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Beltsville Agricultural Research Center,
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ERRATUM

In the process of printing this report, the unit for carbon dioxide concentration was inadvertently misprinted in a number of cases. The correct unit should be micromoles per mole ($\mu mol\ mol^{-1}$). This unit is equivalent to microliters per liter ($\mu l\ l^{-1}$), microbars per bar ($\mu bar\ bar^{-1}$), or part per million (ppm).

Global Climate Change Research Report—1992

Beltsville Agricultural Research Center, Natural Resources Institute

compiled by Donald T. Krizek

Introduction

This report covers the activities of scientists at the Beltsville Agricultural Research Center (BARC) who are involved in research on global climate change. The report covers work done primarily in four laboratories in the Natural Resources Institute (NRI) in the areas of hydrology, remote sensing, systems research, and climate stress effects. Work conducted in the Environmental Chemistry Laboratory in NRI and in the Molecular Biology Laboratory and the Fruit Laboratory in the Plant Sciences Institute is also included.

Section 1 covers highlights of research conducted in CY 1992. A short description is given of the purpose, accomplishment, and significance of the research. For further information, the reader is referred to the 1992 CRIS Annual Reports.

Section 2 contains a list of peer-reviewed papers published in scientific journals in 1992.

Section 3 contains a list of non-peer reviewed papers published in 1992. These include book chapters, proceedings of meetings and other documents not normally subjected to peer review.

Section 4 contains a list of relevant abstracts of papers published in 1992.

Section 5 contains abstracts and interpretive summaries of manuscripts submitted for ARS approval during CY 1992. This section was obtained through the ARS TEXTRAN (Technology Transfer Automated Retrieval System) and was modified to fit on one page.

Section 6 contains a list of scientists with their addresses, phone numbers and fax numbers. For sake of brevity, only permanent scientists have been listed. Inquiries of post-doctoral research associates and visiting scientists may be directed to the main office of each laboratory.

BARC scientists are actively involved in research to better understand possible physical and biological changes that might result from global climate change. Research is underway: (1) to develop improved data bases and models of plant growth; 2) to determine possible hydrologic changes; 3) to develop improved radiative transfer models; 4) to understand the biochemical and physiological mechanisms of adaptation to CO_2 enriched atmospheres, air pollutants, and increased UV-B radiation; and 5) to determine the interactive effects of CO_2 and other environmental factors including tropospheric ozone, UV-B radiation, temperature, and water stress.

Section 1—Research Accomplishments 1992

1992 Research Summaries of Global Climate Change Research at BARC

A. Hydrologic Studies

Climate Change Impacts Water Supplies

The Snowmelt Runoff Model (SRM) was employed to simulate the effects on snowmelt runoff that might result from an increase in atmospheric CO_2, an increase in air temperature, and resulting changes in basin conditions. A temperature increase of 5°C would reduce total seasonal snowmelt runoff by 6%, however, CO_2-induced reductions in transpiration could offset this decrease in flow so that total seasonal flow increases of as much as 11% might occur. Even more important was the effect of redistributing snowmelt to early Spring months, e.g., in Western U.S. basins April runoff could increase in excess of 200% as a result of the climate change. Although the effect on seasonal flow is somewhat variable, a warmer climate could cause major increases in flood events early in the snowmelt season which could result in significant economic losses.
CRIS 1270-13000-004-00D/Rango

Quantifying Hydrologic Fluxes With Remote Sensing

Interdisciplinary field studies have been conducted in different climatic regions to investigate the feasibility of quantifying the surface energy and water balance at basin scales. This capability is crucial for climate modelers because proper treatment of the feedbacks between surface and atmospheric processes is necessary in order to monitor and predict the impact of climate change on the hydrologic cycle. Results from HAPEX, FIFE and MONSOON 90 indicate a potential for utilizing remote sensing in energy balance and hydrologic models. However, the interpretation of the remotely-sensed data and how this information can be utilized in models requires more field studies and model development.
CRIS 1270-13000-004-00D/Kustas/Humes

ARS Water Data Base Goes On-Line

ARS currently has a wealth of long-term hydrologic data that are extremely valuable in evaluating the effects of global change. ARS experimental watershed data have been compiled and stored by the Water Data Center. All data in the ARS Water Data Base are currently available through a dial-up phone system which is connected to an on-line data management system. Development of a CD-ROM using a Graphical User Interface has been stored. 184 station years of air temperature data have been added to the data base for use in assessing global change. Scientists within ARS, other agencies, and private industry use the data in the ARS Water Data Base for various aspects of global change research.
CRIS 1270-13660-004-00D/Rango/Thurman

Airborne Laser Measurements of Aerodynamic Roughness

A new method was developed to estimate aerodynamic roughness lengths using a laser altimeter mounted in a small airplane to measure changes in topography and vegetation heights on the landscape. The measurements of vegetation heights were used to calculate short scale landscape aerodynamic roughness lengths while the measurements of topography were used to measure long scale aerodynamic roughness lengths. The calculated aerodynamic roughness lengths will allow better estimates of energy fluxes over complex terrain. Such an application of airborne laser altimeter and potential satellite altimeter data to measure aerodynamic roughness provides an exciting new method to provide measurements over large areas for use in estimating parameters for local, regional and global modelling efforts of energy fluxes and evapotranspiration.
CRIS 1270-13660-003-00D/Ritchie

B. Remote Sensing

Analysis and Interpretation of Remotely Sensed Data for Agricultural Information

A procedure has been developed for inferring leaf area index (LAI) from remotely sensed data. The method uses reflectance measurements in the visible and near infrared (NIR) region to eliminate effects of variable soil reflectance, which otherwise causes a confusing signal which results in an error in the estimate of LAI. The formulation depends on three variables for both visible and NIR wavelengths: the reflectance of dense vegetation, the reflectance of bare soil, and the transmittance of the vegetation canopy to radiation. Values for two of the three variables may frequently be estimated from LANDSAT satellite data representing an agricultural area. However, the transmittance values must be obtained from field experiments for each vegetation type. This method should prove useful to the Foreign Agricultural Service (FAS) and the National Agricultural Statistics Service in obtaining large area estimates of the growth of agricultural crops. This technique should also be helpful in assessing the calibration of visible and NIR channels of the NOAA satellites. Improved quantitative understanding of these data should help FAS in tracking the status of agriculture abroad where acquisition of LANDSAT data is too expensive for routine use.
CRIS 1270-66000-007-00D/Price

Measuring and Modeling Reflected, Absorbed and Emitted Radiation from Plant Canopies

Algorithms using reflectance spectra were developed and refined to measure concentrations of chlorophyll a, chlorophyll b, and caroteinoids. The 'red edge shift' in reflectance spectra was found to be primarily related to chlorophyll concentration. The fraction of absorbed photosynthetically active radiation may be estimated from multispectral remotely sensed observations and used to estimate phytomass production. These results clearly indicate that remotely sensed measurements contribute valuable information concerning energy/mass accumulation in plant canopies.
CRIS 1270-66000-010-00D/Chappelle/McMurtrey

Estimating Photosynthetically Active Radiation from Satellite Data

Further efforts were made to develop methods and software to calibrate NOAA AVHRR satellite sensors. This is important for monitoring long-term changes in agriculture and climate as the sensors on the satellites change with age and new sensors are developed. Another crucial task for monitoring changes in vegetation is the correction of satellite data for atmospheric variability. To do this, the Satellite Signal in the Solar Spectrum (5S) was implemented and adapted for operational use. Several techniques were developed to generate the atmospheric optical parameters required to calculate reflected irradiances at the ground level. Phytomass production is proportional to the amount of radiation absorbed by plants where other factors are not limiting. Relationships between absorbed radiation, phytomass, and multispectral reflectance of crops were examined. Results of this research support the crop condition and assessment mission of the National Agricultural Statistics Division and the Foreign Agricultural Service.
CRIS 1270-66000-010-01S/Daughtry

C. Systems Research

Modeling Photosynthesis and Stomatal Control

Crop models are being used to assess the impact of projected global climate change. Based on our present understanding, carbon dioxide concentration, temperature, and rainfall are all expected to change, but our knowledge of how these affect crop yield and water use is incomplete. Data on photosynthesis and transpiration of tomato leaves were collected in collaboration with Jim Bunce, Climate Stress Lab. Responses to temperature,

light, and CO_2 concentration were measured on plants grown at 350 and 700 ìmol mol^{-1} CO_2. Three of the most popular photosynthesis models were fitted to the data and the parameter values were examined for correlations with environmental variables. Several supplementary models were developed to account for the variation in parameter values. This work is directed to developing a more realistic model of leaf photosynthesis and stomatal activity and hence, crop yield and water use.
CRIS 1270-61000-012-OOD/Pachepsky

Potential Farmer Responses to Climate Change

Based on our understanding of crop response to environment, a paper was prepared discussing how farmers are likely to change their management practices to minimize any disruptive effects of future climate change. The paper stressed the need to take into account such changes in assessing the impact of climate change. Since we have fine-tuned our management to present conditions, any change in those conditions is likely to lead to a predicted yield decline unless the flexibility and versatility of farmers is also acknowledged.
CRIS 1270-61000-012-OOD/Acock

Estimating Yields Over Large Areas

Most crop models that are used to assess the impact of global climate change operate on a field scale. Soil and weather are assumed to be the same over the whole area covered by the crop. Several methods of aggregating yield from field-scale to state-scale have been proposed, but none has been tested. To remedy this situation, soils and weather data were collected for Iowa. From the limited soil data available (mostly texture) additional soil characteristics were calculated (e.g. the water release curve and hydraulic conductivity). Within each of the major soil series present in Iowa, soil characteristics (parameters) were analyzed and their distribution characterized. This work will eventually give us a methodology for predicting yield over large areas using field-scale crop models.
CRIS 1270-61000-012-OOD/Haskett

Modeling Effects of Carbon Dioxide Concentration and Temperature on Cotton Phenology and Growth

Most cotton simulation models have been developed with data collected from a narrow temperature range and hence have limited predictive capabilities under the temperature extremes that might be encountered in the future. The results of experiments with cotton covering suitably wide ranges in temperature and carbon dioxide concentration were described in last years report. These data were used to develop new models of cotton phenology and potential growth rate. These models were then added to a complete cotton crop model substituting for earlier subroutines. The new model will be used in assessing the impact of possible future climate change on agriculture.
CRIS 1270-61000-012-OOD/Reddy

D. Biochemical and Physiological Effects

Foliar Starch, Sucrose and 3-Carbon Phosphoester Levels Influence the Rate of Dark Respiration in CO_2 Enriched Soybean Leaves

The influence of CO_2 enrichment on respiratory metabolism of young soybean plants was investigated as a means of examining the possible influence of elevated CO_2 in the atmosphere on crop productivity. When soybean plants were acclimated to concentrations of 1000 ìmol mol^{-1} CO_2 vs 350 ìmol mol^{-1} CO_2, there was an 1.5 fold increase in their foliar photosynthetic CO_2 assimilation rate and a two-fold increase in biomass accumulation. There was also a dramatic increase in the foliar CO_2 compensation concentration (measured in the light) which was interpreted to be a reflection of elevated foliar respiration in the light as well as in the dark. Increased plant growth was positively correlated with increased foliar respiration rate. In high CO_2 exposed plants, the higher foliar respiration rate apparently was brought on by increased levels and availability of potential respiratory substrates, e.g. foliar starch, sucrose and 3-carbon phosphoesters. The leaf cell organelles where these respiration in-

creases occurred are not known. However, since foliar photorespiration was greatly repressed in CO_2 enriched plants as compared to CO_2 normal plants, the site of increased respiration rate probably was not the leaf peroxisomes. Elevated starch and hexose phosphate levels in the chloroplast and elevated sucrose and triose phosphate levels in the cell cytoplasm suggest that both leaf chloroplasts as well as mitochondria could have been sites of increased decarboxylation rates, i.e., chloroplast and mitochondrial dark respirations. This research should provide information to plant ecologists and crop modelers to enable them to predict plant behavior at elevated CO_2.
CRIS 1270-21000-014-00D/Robinson

Response to Elevated CO_2 Depends on Plant Growth Lighting

Soybeans were grown at 400 or 700 µmol mol^{-1} CO_2 in growth chambers (GC) under two types of lighting, each providing c. 44 mol m^{-2} photosynthetically active radiation (PAR) per day. One source consisted of HID lamps (50:50 mixture of high pressure sodium and metal halide bulbs) with an average PAR of 875 µmol m^{-2} s^{-1} over 14 h. This combination provides relatively little blue or far-red radiation. The second source consisted of two microwave-driven, sulfur-filled, electrodeless plasma (MEP) lamps with an emission spectrum closer to natural sunlight and a peak PAR of 1650 µmol m^{-2} s^{-1}. Plants grown under MEP lamps were more like greenhouse (GH)-grown plants than HID-grown plants in Leaf Area Ratio, Specific Leaf Weight and stem and petiole lengths. However, GH-grown plants had much less axillary development than either group of GC-grown plants. At low CO_2, MEP plants had less dry matter than HID plants at a given developmental stage. This relationship was significantly reversed at high CO_2 with MEP plants outperforming HID plants. Differences in photosynthesis did not account for the growth response. Morphological adaptations, possibly influenced by spectral quality, may have resulted in increased light utilization efficiency.
CRIS 1270-11210-002-00D/Britz/Krizek

An Inhibition of Photosynthesis Occurs in Atmospheres Containing Elevated CO_2

Decreased net carbon assimilation rates were observed 7 to 10 days after Nicotiana plants were transferred from normal air to twice the ambient CO_2 concentration. A corresponding decrease occurred in both extractable activity and protein amounts of the principal CO_2 fixing enzyme in the leaf, ribulose 1,5-bisphosphate carboxylase oxygenase (i.e., rubisco). Similar results were obtained with transgenic *Nicotiana* plants containing antisense DNA sequences designed to decrease the rubisco protein concentration by one-half. These findings suggest that decreased carboxylase levels during growth in elevated CO_2 are not a response to an excess pool of rubisco protein.
CRIS 1270-21000-012-00D/Sicher

Elevated CO_2 Reduces Maintenance Respiration Per Unit of Protein

The reduction in whole plant respiration rate caused by growth at twice the current atmospheric CO_2 concentration was examined in alfalfa and orchard grass. Reductions in respiration rate occurred primarily at lower growth temperatures, and contributed to the greater stimulation of biomass production by elevated CO_2 at the lower temperatures. Both the growth and maintenance components of respiration were reduced. The elevated CO_2 concentration reduced the rate of maintenance respiration per unit of protein at the lower temperatures. The results indicate that the reduction in maintenance respiration at elevated CO_2 is not simply related to lower protein content of the tissue.
CRIS 1270-21000-011-01T/Bunce/Ziska

One Night at High CO_2 Reduces Photosynthesis

Long-term exposure of many plants to twice the current atmospheric concentration of CO_2 reduces their photosynthetic capacity, and reduces the stimulation of growth caused by elevated CO_2. It has been hypothesized that the reduction in

photosynthetic capacity is caused by feedback inhibition or by nitrogen deficiency. It was found in sunflower and amaranth that exposure of leaves to a single night at doubled CO_2 reduced photosynthetic capacity as much as long-term exposure. A similar response was previously noted in soybean. These results make it unlikely that either feedback inhibition or nitrogen deficiency cause the reduction in photosynthetic capacity in these species.
CRIS 1270-21000-011-00D/Bunce

Rising Global Atmospheric CO_2 May Counteract the Detrimental Effects of Air Pollutants on Crop Plants

Crop damage from ozone (O_3) & sulfur dioxide (SO_2) in the U. S. has been estimated to exceed several billion dollars annually. Studies were conducted from 1988-1992 to determine the effects of increasing atmospheric CO_2 and its interaction with air pollutant stress on the growth and yield of soybeans, winter wheat, corn and cotton. Using open-top chambers, field plots of crop plants were exposed to season-long CO_2 concentrations of ambient (about 350 ìmol/mol) and elevated (500 ìmol/mol) CO_2. Studies in 1988-90 involved interactive effects of CO_2 and O_3, while those in 1991 and 1992 focused on combined effects of CO_2 and SO_2. The CO_2 and air pollutant interactions observed were generally consistent with a reduction of air pollutant injury under increased CO_2. Rising CO_2 may thus ameliorate the detrimental effects of air pollutants on crop plants.
CRIS 1270-23000-004D/Lee

Pre-Treatment of Plants Under Inverted Temperatures Prevents Damage from Air Pollutants

Antioxidants such as vitamin C, vitamin E, glutathione and polyamines may be involved in plant adaptive mechanisms against oxidative stress caused by air pollutants and other environmental stresses. Changes in antioxidants may lead to altered crop yields by changing plant susceptibility to air pollutants. This study demonstrated that pre-treatment of snap bean plants at inverted (18/28°C) day/night (D/N) temperature resulted in a greater increase in free polyamines as compared to pre-treatment at a normal (28/18°C) D/N temperature. This increase in polyamine titer during pre-treatment under inverted D/N temperature appeared to be directly correlated with the reduction in visible injury when fumigated with 0.3 ìmol mol^{-1} O_3 or 0.5 ìmol mol^{-1} SO_2 for 3 hr.
CRIS 1270-23000-004D/Lee

Influence of Inverse Day/Night Temperature on Ozone Sensitivity and Selected Morphological and Physiological Responses of Cucumber

Studies were conducted to determine the use of inverse day/night (D/N) temperature as a non-chemical means of controlling plant growth. Cucumber plants grown from seed in a growth chamber under an inverse day/night temperature of 18/28°C for 24 days prior to ozone (O_3) fumigation (3 h at 0.5 ìmol/mol) showed a significant reduction in height, node number, fresh weight, dry weight and leaf area as compared to those grown under a normal day/night (D/N) temperature of 28/18°C. Photosynthetic rate (Pn) and chlorophyll concentration were lower and O_3 injury and polyamine levels were greater at 18/28°C than at 28/18°C D/N temperature. Ozone generally increased the concentration of polyamines and reduced the Pn rate and stomatal conductance. Since global warming is currently expected to have a greater effect on night temperature than day temperature, these findings should be of interest to policy makers and scientists involved in research on climate change.
CRIS 1270-11210-003-00D/Agrawal/Krizek/Lee

Investigation of Rapid Responses of Plants to Various Environmental Stresses

Even though different environmental stresses may result in the production of excess intracellular prooxidants, the initial mechanisms may not be the same. Therefore, the use of simplified systems which measure both specific and non-specific stress related responses in excised plant tissue could yield important information. Cotyle-

don discs of cucumber plants were exposed to different levels of high temperature for various time periods. Significant changes in some acidic amino acids, cysteine and glutathione were found even after very short (5 min) exposure to high temperature. The extent of recovery was different for different temperature treatments. This system also provided useful information on the effect of bisulfite on glutathione, cysteine, aspartate and glutamate. These effects were similar to those obtained with intact plants fumigated with sulfur dioxide. Therefore, it may be possible to determine the cellular mechanisms for rapid plant responses to SO_2 and the alleviation of SO_2-induced damage by exogenous agents.
CRIS 1270-21000-001-01T/Upadhyaha/Caldwell

Interactions Between Blue Light and UV-B Radiation

High irradiance background white light generally reduces damage to plants from UV-B radiation, but the mechanisms responsible for amelioration of damage are not well understood. The role of blue light photoreceptors in this process was investigated using 2 cultivars of cucumber (*Cucumis sativus* L. cvs Poinsett or Ashley) differing in UV-sensitivity. Plants were grown in white light without UV-B at high photosynthetically-active radiation (PAR) and then transferred for up to 10 h to a second chamber for UV-B treatment. This chamber provided high PAR from amber low pressure sodium lamps with optional supplemental blue light. Short-term UV-B radiation (6-8 h) significantly inhibited leaf expansion and induced chlorotic lesions in cv Poinsett when delivered in the absence of supplemental blue light. Blue light (60 μmol m^{-2} s^{-1}), provided during UV, largely prevented these symptoms, consistent with possible photoreactivation of UV damage to DNA. Blue light stimulation of UV-absorbing pigments was detected only after 10 h of irradiation, too late to account for protection. Damage to the 3rd leaf of cv Ashley was not observed for short UV treatments (10 h or less), but a rapid UV-B induction of UV-absorbing pigments was measured within 4 h after the start of UV. The increase was significantly enhanced by simultaneous blue light. Alternative approaches are required to determine if changes in pigments affect cryptic UV-B damage in cv Ashley.
CRIS 1270-11210-002-01T/Adamse/Britz

Genetic Basis for Sensitivity to UV-B Radiation in Glycine

Twelve different cultivars of soybean (*Glycine max* [L.] Merr.) were screened in a greenhouse for sensitivity to supplemental UV-B radiation simulating ca. 25% ozone depletion at 39°N. Substantial variation in sensitivity was observed based on dry matter and seed yield. Resistance to UV-B was correlated with increased leaf flavonoid content and increased specific leaf weight. Although considerable genetic variability to UV-B was apparent, most domestic soybean cultivars stem from a small number of ancestral lines. We are therefore seeking to assess variability in natural populations of a related species, *Glycine tomentella,* collected along latitudinal and elevational gradients from Papua New Guinea to New South Wales, Australia. It is hypothesized that these accessions will reveal a broader range of responses to UV-B radiation, with lines from high UV environments (i.e., low latitude, high altitude) being more resistant. This study may identify UV-B tolerant germplasm which could be incorporated into soybean breeding programs. Since atmospheric CO_2 is rising, an additional goal of this project is to assess the interaction between CO_2 level and sensitivity to UV-B.
CRIS 1270-11210-003-00D/Reed/Teramura/Britz

Modification of Thermal and Bisulfite Sensitivity of Cucumber by UV-B Pretreatment

Growth of cucumber seedlings under elevated UV-B radiation equivalent to about 20% reduction in stratospheric ozone reduced the sensitivity of plant tissues to hyperthermia and bisulfite. The levels of several enzymatic and nonenzymatic antioxidants were higher in UV-B grown plants in comparison to controls both before and after bisulfite and high temperature treatments. Since hyperthermia, bisulfite and elevated UV-B are all

oxidative stresses, and both high temperature and UV-B induce the synthesis of heat shock proteins, there may be common inducible pathways that protect plants from multiple environmental stresses. Our results suggest that low level pre-treatment of plant tissues with one kind of oxidative stress may subsequently result in increased tolerance to other acute stresses.
CRIS 1270-21000-001-01T/Upadhyaha/Caldwell

UV-B Induction of Ethylene and Accelerated Senescence in Pear Shoots Grown In Vivo.

Ethylene is one of the main compounds induced by stress in plants. Polyamine metabolism is also frequently altered. In this study, in vitro shoots of cv. Doyenne d'Hiver pear were irradiated under controlled environments for 6 hr per day at five levels of biologically effective UV-B radiation ($UV\text{-}B_{BE}$). UV-B caused a progressive increase in apical necrosis above background levels and stimulated leaf abscission. Shoots grown for 2 weeks at 8.4 or 12.0 kJ m^{-2} d^{-1} of $UV\text{-}B_{BE}$ produced up to 4 times more ethylene than those given 2.2 or 5.1 kJ m^{-2} d^{-1} of $UV\text{-}B_{BE}$ or untreated controls. Exposure of shoots to 12 kJ m^{-2} d^{-1} caused an increase in free putrescine after 4 to 14 days. CO_2 uptake decreased after 3 days of UV-B and then showed recovery. This is the first report of UV-B induction of ethylene in vitro.
CRIS 1275-21000-071-00D/Predieri/Krizek/Wang/Zimmerman

UV-B Radiation and CO_2 Enrichment Effects on Crop Growth in India

No differences in growth or yield of mungbean or cowpea plants were observed in UV-B exclusion studies conducted in New Delhi during 1991-92. This was in contrast to studies conducted during 1990 in which growth and yield were inhibited by ambient UV-B. Wheat, mustard, sunflower, and mungbean grown in open-top chambers under 600 μmol mol^{-1} CO_2 showed increased plant height, leaf area, and total biomass vs those grown at ambient CO_2. High CO_2 hastened flowering in wheat and mungbean and increased grain yield. It also increased photosynthesis, starch and reducing sugars and decreased respiration, amino acids, non-reducing sugars, and chlorophyll. These findings are important to policy makers and scientists in assessing the possible impact of global change in the tropics.
CRIS 8000-11210-758-00P/Abrol/Sharma/Sengupta/Krizek

Importance of PAR and Spectral Quality in Determining Response of Soybean Plants to UV-B Radiation

The effects of UV-B radiation on plant growth and polyamine levels in Essex and Williams soybean were greatly influenced by the level of visible light (PAR) and the spectral quality of the lamps. Exposure of soybean plants to UV-B radiation significantly reduced stem elongation at 300 μmol m^{-2} s^{-1} PAR but not at 600 μmol m^{-2} s^{-1} of PAR when a balanced spectrum provided by a combination of metal halide (MH) and high pressure sodium/deluxe (HPS/DX) lamps was used. This is consistent with findings of other workers who have demonstrated protection from UV-B by high PAR. Our results suggest that polyamines could be involved in this photoprotective effect of high PAR. PAR increased putrescine levels under metal halide (MH) lamps but not high pressure sodium/deluxe (HPS/DX) lamps. UV-B inhibited growth at both PAR levels when plants were grown under either of the two radiation sources alone. There was no effect of PAR on the UV-B induced growth inhibition with HPS/DX lamps but a partial amelioration of this inhibition in Williams at high PAR. These results indicate that the inhibition of UV-B stress by high PAR may require a balance of red and blue wavelengths and may involve polyamine accumulation.
CRIS 1270-11210-0003-00D/Kramer/Krizek

UV-B Induced Damage to PSII Reaction Center Proteins and Adaptive Protection

Plants exposed to UV-B irradiation show alterations in growth, development, transpiration and photosynthesis. The effect on photosynthesis seems directed at photosystem II (PSII). We have

found that UV-B increases the degradation of an essential protein component of PSII, D1. A synergistic effect was observed between red light and UV-B irradiation. Preliminary indications are that in addition to D1, its sister protein D2, which is relatively stable in red light, also undergoes rapid degradation in UV-B. Experiments in progress are designed to test if the D1-D2 heterodimer is in fact the target of UV-B damage. These results are important to scientists interested in environmental issues and in designing strategies to combat possible UV-B injury to plants. CRIS 1275-21000-060-02T/Mattoo

Impact of Severe Drought Stress on Seed and Fiber Maturity in Cotton

The impact of severe drought stress on seed and fiber maturation was evaluated in four cultivars of cotton (DP-51, 91, 50 and MD-51) grown in the greenhouse. Drought stress was imposed by withholding water. Following drought treatment, ovules were excised from bolls on control and drought-stressed plants 20 to 50 days after anthesis (DPA) for evaluation. Changes in fiber properties were determined through analysis of dry weight, length, and dyeability. Whole seeds and excised embryos were weighed and these weights were compared to that of carpel and bract of open bolls. Differences in gravimetric measurements were most noticeable for both embryo and fiber for seeds from open bolls subjected to severe drought at 20 to 30 DPA. This sensitive window of development corresponds to the initiation time for storage of food reserves in the embryo and deposition of cellulose secondary walls in the fiber. These findings will benefit producers, seed companies, ginners, plant breeders and plant physiologists, and the Soil Conservation Service. CRIS 1270-11210-004-00D/Vigil/Fang

Section 2—Peer-Reviewed Publications 1992

BARC Publications on Global Climate Change 1992

A. Hydrologic Studies

Armstrong, R. I., A. Chang, A. Rango, and E. G. Josberger. 1992. Snow depths and grain size relationships with relevance for passive microwave studies. Ann. Glaciology 14: In Press. 10 pp.

Chang, A. T. C., J. L. Foster, and A. Rango. 1992. The role of passive microwaves in characterizing snow cover in the Colorado River basin. GeoJournal 26(3):381-388.

Dey, B., V. K. Sharma, and A. Rango. 1992. Linear or nonlinear covariance of seasonal snowmelt and snow cover in western Himalayas. Nordic Hydrology 23:183-192.

Field, R. T., L. J. Fritschen, E. T. Kanemasu, E. A. Smith, J. B. Stewart, S. B. Verma, and W. P. Kustas. 1992. Calibration, comparison and correction of net radiation. J. Geophysical Research 97(D7):18681-18696.

Jackson, T. J. et al. 1992. Soil moisture verification study of the ESTAR microwave radiometer: Walnut Gulch, AZ 1991. IGARSS '92. IEEE Publ. 92CH3041-1:486-488.

Jackson, T. J. et al. 1992. Multifrequency passive microwave sensors observations of soil moisture in an arid rangeland environment. Int. J. of Remote Sens. GE-30:610-616.

Josberger, E. G., W. G. Campbell, P. Gloerson, A. T. C. Chang, and A. Rango. 1992. A nine-year history of snow conditions in the upper Colorado River basin. Ann. Glaciology 14: In press. 14 pp.

Kanemasu, E. T., S. B. Verma, E. A. Smith, L. J. Fritschen, M. Wesely, R. T. Field, W. P. Kustas, et al. 1992. Surface flux measurements in FIFE: An overview. J. Geophysical Research 97(D7):18547-18556.

LeVine, D. M., A. Griffis, C. T. Swift, and T. J. Jackson. 1992. ESTAR: A syntheticaperture microwave radiometer for measuring soil moisture. IGARSS'92. IEEE Publ. 92CH3041-1:483-485.

Nie, D., E. T. Kanemasu, L. J. Fritschen, H. L. Weaver, E. A. Smith, S. B. Verma, R. T. Field, W. P. Kustas, and J. B. Stewart. 1992. An intercomparison of surface energy flux measurement systems used during FIFE 1987. 97(D7):18715-18724.

O'Neill, P. N. Chauan, S. Saaichi, and T. Jackson. 1992. Synergistic use of active and passive microwave in soil moisture estimation. IGARSS '92. IEEE Publ. 92CH3041-1:492-494.

Rango, A. 1992. Worldwide testing of the Snowmelt Runoff Model with applications for predicting the effects of climate change, Nordic Hydrology, 23, pp. 155-172.

Schmugge, T. J., T. J. Jackson, W. P. Kustas, and J. R. Wang. 1992. Passive microwave remote sensing of soil moisture: results from HAPEX, FIFE and MONSOON 90. ISPRS J. of Photo. and Remote Sensing 47:127-143.

Smith, E. A., A. Y. Hsu, W. L. Crosson, R. T. Field, L. J. Fritschen, R. J. Gurney, E. T. Kanemasu, W. P. Kustas, et al. 1992. Area-averaged surface fluxes and their time-space variability over the FIFE experimental domain. J. Geophysical Research 97(D7):18599-18622.

B. Remote Sensing

Rango, A. 1992. Workshop on remote sensing algorithms. EOS Trans. Amer. Geophysical Union 73:(13):147-149.

Ritchie, J. C., J. H. Everitt, D. E. Escobar, T. J. Jackson, and M. R. Davis. 1992. Airborne laser measurements of rangeland canopy cover and distribution. J. Range Management 45(2):189-193.

Ritchie, J. C., T. J. Jackson et al. 1992. Airborn laser: a tool to study landscape features. J. Soil and Water Conservation 47(1):104-107.

Schiebe F. R., J. A. Harrington, Jr., and J. C. Ritchie. 1992. Remote sensing of suspended sediments: The Lake Chicot project. Intl. J. of Remote Sensing. 13:1487-1509.

Schmugge, T. J. and T. J. Jackson. 1992. Dielectric model of the vegetation effects on the microwave emission from soils. IEEE Trans. on Geoscience and Remote Sensing. GE-30:757-760.

C. Systems Research

Reddy, K. R., H. F. Hodges, and V. R. Reddy. 1992. Temperature effects on cotton fruit retention. Agron. J. 84:26-30.

Reddy, K. R., V. R. Reddy, and H. F. Hodges. 1992. Temperature effects on early season cotton growth and development. Agron. J. 84:229-237.

Reddy, V. R. 1992. Modeling mepiquat chloride-temperature interactions in cotton: The model. Computers and Electronics in Agriculture 8: In Press.

Timlin, D. J., G. C. Heathman, and L. R. Ahuja. 1992. Solute leaching in crop row vs. interrow zones. Soil Sci. Soc. Am. J. 56(2):384-392.

D. Biochemical and Physiological Effects

Adamse, P. and S. J. Britz. 1992. Amelioration of UV-B damage under high irradiance. I. Role of photosynthesis. Photochem. Photobiol. 56:645-650.

Adamse, P. and S. J. Britz. 1992. Spectral quality of two fluorescent UV sources during long-term use. Photochem. Photobiol. 56:641-644.

Agrawal, S. B., M. Agrawal, E. H. Lee, G. F. Kramer, and P. Pillai. 1992. Changes in polyamine and glutathione contents of a green alga, *Chlorogonium elongatum* (Dang) France exposed to mercury. Envir. & Exp. Bot. 32:145-151.

Bunce, J. A. 1992. Light, temperature and nutrients as factors in photosynthetic adjustment to elevated concentration of carbon dioxide. Physiol. Plant. 86:173-179.

De Veau, E. J. I., J. M. Robinson, R. D. Warmbrodt, and D. F. Kremer. 1992. Photosynthate metabolism in the source leaves of N_2-fixing soybean plants. Plant Physiol. 99:1105-1117.

Dubik, S. P., D. T. Krizek, D. P. Stimart, and M. S. McIntosh. 1992. Growth analysis of spreading euonymus subjected to root restriction. J. Plant Nutr. 15(4):469-486.

Elich, T.D., M. Edelman and A.K. Mattoo. 1992. Identification, characterization and resolution of in vivo phosphorylated form of the D1 photosystem II reaction center protein. Jour. Biol. Chem. 267(5):3523-3529.

Kramer, G. F., D. T. Krizek, and R. M. Mirecki. 1992. Influence of photosynthetically active radiation and spectral quality on UV-B induced polyamine accumulation in soybean. Phytochemistry 31(4):1119-1125.

Lee, E. H. 1992. Plant resistance mechanisms to air pollutants: Rhythms in ascorbic acid production during growth under ozone stress. Chronobiology International 8(2):93-102.

Lee, E. H., G. F. Kramer, R. A. Rowland, and M. Agrawal. 1992. Antioxidants and growth regulators counter the effects of O_3 and SO_2 in crop plants. Agric. Ecosystems and Environ. 38:99-106.

Lee, E. H., R. Pausch, R. Rowland, L. Slaughter, M. Saleem, and C. L. Mulchi. 1992. Growth and physiological characteristics of soybean in open top chambers in response to ozone and increased atmospheric CO_2. Agric. Ecosystems and Environ. 38:107-118.

McCauley, S. W., A. P. Baronavski, J. K. Rice, M. L. Ghirardi and A. K. Mattoo. 1992. A search for subpicosecond absorption components in photosystem II reaction center. Chem. Phys. Lett. 198:437-442.

Mehta, R.A., T.W. Fawcett, D. Porath and A.K. Mattoo. 1992. Oxidative stress causes rapid membrane translocation and in vivo degradation of ribulose-1,5-bisphosphate carboxylase/ oxygenase. Jour. Biol. Chem. 26(4):2810-2816.

Mulchi, C. L., L. Slaughter, M. Saleem, E. H. Lee, R. Pausch, and R. A. Rowland. 1992. Growth and physiological characteristics of soybeans in open-top chambers in response to ozone and increased atmospheric CO_2. Agri. Ecosystems & Environ.38: 107-118.

Reed, H. E., A. H. Teramura, and W. J. Kenworthy. 1992. Ancestral U.S. soybean cultivars characterized for tolerance to ultraviolet-B radiation. Crop Sci. 32:1214-1219.

Rudorff, B. F. T., C. L. Mulchi, C. S. T. Daughtry, and E. H. Lee. 1992. Effects of enriched carbon dioxide and ozone stress on canopy reflectance and grain yield in winter wheat. Remote Sens. & Data Acquisition 4: 108-115.

Sullivan, J. H., A. H. Teramura, and L. H. Ziszka. 1992. Variation in UV-B sensitivity in plants from a 3,000-m elevational gradient in Hawaii. Amer. J. Bot. 79(7):737-743.

Ziska, L. H., K. P. Hogan, and A. P. Smith. 1992. Potential effects of elevated CO_2 and changes in temperature on tropical plants. Plant, Cell and Environment 14:763-778.

Ziska, L. H. and A. H. Teramura. 1992. CO_2 enhancement of growth and photosynthesis in rice (*Oryza sativa*). Physiol. Plant. 84:473-481.

Ziska, L. H. and A. H. Teramura. 1992. Intraspecific variation in the response of rice (*Oryza sativa*) to increased CO_2 - photosynthetic biomass and reproductive characteristics. Physiol. Plant. 84:269-276.

Section 3—Non-Peer-Reviewed Publications 1992

BARC Publications on Global Climate Change 1992

A. Hydrologic Studies

Armstrong, R. and A. Rango. 1992. Monitoring snow grain size for passive microwave studies. Proc. 60th Annual Eastern Snow Conf. pp. 46-65.

Jackson, T. J. and T. J. Schmugge. 1992. Surface soil moisture measurements with microwave radiometry. Proc. Int. Astronautical Federation. Paper IAR 92-0122.

Martinec, J., A. Rango, and R. Roberts. 1992. Rainfall-snowmelt peaks in a warmer climate. Proc. Symposium on Managing Water Resources During Global Change. American Water Resources Association, Reno, Nevada. pp. 195-202.

Rango, A., Thurman, J., Blackburn, W., Schiebe, F., and Woolhiser, D. 1992. Compilation and availability of Agricultural Research Service hydrological data for use in climate change studies. Proc. NATO Workshop on Opportunities for Hydrological Data in Support of Climate Change Studies, Lahnstein, Germany. NATO Publication Series.

Schmugge, T. J., T. J. Jackson, D. Goodrich, and S. Amer. 1992. PBMR observations of surface soil moisture in MONSOON 90. Proc. Spec. Mtg Microwave. Rad. and Remote Sensing Applic. pp. 72-77.

Schmugge, T. J. and T. J. Jackson. 1992. Mapping surface soil moisture with the PBMR. Proc. International URSI Conference on Microwave Terrestrial Remote Sensing. pp. 2D9-D12.

Thurman, J. L. 1992. "REPHLEX II: An information management system for the ARS water data base" Proc. ISY Conference on Earth and Space Information Systems. Pasadena, CA. 8 pp.

Weichelt, H., A. Shutko, B. Reutov, T. Jackson, and T. Schmugge et al. 1992. Progress and problems in microwave radiometric sensing of soil moisture. ISPRS Congress. Paper 583.

B. Remote Sensing

Anderson, G. L., J. D. Hanson, and G. F. Hart. 1992. Developing relationships between green biomass and LANDSAT Thematic Mapper .... Proc. ASPRS/ACSM/RT92, Washington, D.C. August 3-8, 1992. 4:355-363.

Brutsaert, W., A. Hsu, and T. J. Schmugge. 1992. Parameterization of surface heat fluxes above a forest with satellite thermal sensing. Proc. IGARSS'92, Houston, TX, May 26-29, 1992. pp. 1505-1507.

Chanzy, A., J. P. Wigeron and T. J. Schmugge. 1992. Multifrequency microwave measurements with PORTOS ... Proc. of Spec. Mtg. on Micro. Radiom. and Remote Sensing Appl. pp. 67-71.

Chappelle, E. W., J. E. McMurtrey, M. S. Kim and L. A. Corp. 1992. Laser induced fluorescence (LIF) of intact plants. Proc. IX. Intl. Congress Photosynthesis, Hawaii.

Che, N. Z. and J. C. Price. 1992. Visible and near infrared calibration of the NOAA-11 AVHRR. Proc. IGARSS'92 Symposium, Houston, Texas. pp. 3-5.

Daughtry, C. S. T., M. D. Steven, et al. 1992. Remote sensing of absorbed radiation and phytomass production. Proc. 52nd Easter School, Univ. of Nottingham, Sutton Bonington, England.

McMurtrey, J. E. III, C. S. T. Daughtry, E. W. Chappelle and M. S. Kim. 1992. Assessment of fluorescence and reflectance techniques for detecting crop residue from soil. Proc. Beltsville Symposium XVII: 63.

Menenti, M. and J. C. Ritchie. 1992. Estimation of effective aerodyamic roughness with altimeter measurements. Proc. IGARRS '92 Symposium, Houston, Texas. Vol. II. pp. 1508-1510.

Price, J. C. 1992. Estimating leaf area index from remotely sensed data. Proc. IGARSS'92 Symposium, Houston, Texas. pp. 1505-1502.

Ritchie, J.C. and M. A. Weltz. 1992. Using an airborne laser to measure vegetation properties. ASPRS/ASCM/RT 92 Tech. Papers Vol. 4. Remote Sensing and Data Acquisition. pp. 395-404.

C. Systems Research

Acock, B. and M. C. Acock. 1992. Modeling approaches for predicting crop ecosystem responses to climate change. In: D. R. Buxton et. al. (eds.) International Crop Science I. Crop Science Society of America, Madison, WI. In Press.

Lemmon H. and N. Chuk. 1992. Salient physiological and mathematical features of a new cotton model. Proc. Beltwide Cotton Prod. Meetings, Knoxville, TN, January 10, 1992.

D. Biochemical and Physiological Effects

Agrawal, M., S. B. Agrawal, D. T. Krizek, G. F. Kramer, E. H. Lee, R. M. Mirecki, and R. A. Rowland. 1991. Physiological and morphological responses of snapbean plants to ozone stress as influenced by pretreatment with UV-B radiation. In: Impact of Global Climatic Changes on Photosynthesis and Plant Productivity. Y. P. Abrol et al. (eds.) Proc. of the Indo-US Workshop held at New Delhi, India, Jan. 8-12, 1991. Oxford & IBH Publishing Co., Pvt, Ltd., New Delhi. pp. 136-146.

Britz, S. J., P. Adamse and C. R. Caldwell. 1992. Amelioration of UV-B damage. In: Prog. and Abstracts, Eleventh Intl. Congress on Photobiology, Kyoto, Japan, Sept. 7-12, 1992. p. 238.

Foy, C. D. 1992. Soil chemical factors limiting plant root growth. Advances in Soil Science. Vol. 19. Springer-Verlag, New York, Berlin.

Krizek, D. T. 1992. In review: Climate change and plant genetic resources. Book review of Climatic Change and Plant Genetic Resources, by M. T. Jackson, B. V. Ford-Lloyd and M. L. Parry (eds.), Belhaven Press, London, New York. Diversity 8(3):36-37.

Krizek, D. T., R. M. Mirecki and G. F. Kramer. 1992. Effects of spectral quality and PAR on UV-B response of soybean. In: Prog. and Abstracts, Eleventh Intl. Congress on Photobiology, Kyoto, Japan, Sept. 7-12, 1992. p. 239.

Mattoo, A. K. et al. 1992. Light modulation of D1 turnover and PSII dynamics in higher plant chloroplasts. Proc. 28th NIBB Conf., Okazaki, Japan, Feb. 24-Mar. Abstr. p. 3.

Mattoo, A. K. et al. 1992. Post-translational modification of chloroplast proteins and the regulation of protein turnover. Proc. Soc. Expt. Biol. Meeting, Lancaster, U. K., Apr. 3-8, 1992. Abstr. p. 7.

Vigil, E. L. and T. K. Fang. 1992. Impact of drought stress on protein synthesis in developing cotton seeds. Proc. 46th Beltwide Cotton Physiology Conference. p. 1067.

Vigil, E. L. and D. P. Thibodeaux. 1992. Progress on the relationship between fiber and seed quality as affected by drought stress. Proc. 3rd Beltwide Cotton Quality Measurement Conference. p. 1022.

Section 4—Abstracts 1992

A. Hydrologic Studies

Humes, K. S., W. P. Kustas, and T. J. Jackson. 1992. Combined use of visible, near-infrared, thermal and passive microwave remote sensing observations over a semi-arid watershed. EOS Abst. 73:190.

Kustas, W. P., K. S. Humes, L. E. Hipps, M. S. Moran, and R. T. Pinker. 1992. Quantifying basin scale energy fluxes during MONSOON 90. EOS Abst. 73:183.

Kustas, W. P., T. J. Schmugge, K. S. Humes, P. C. Doraiswamy, E. Perry, M. S. Moran, and R. T. Pinker 1992. Remote sensing from plant to watershed scale in semiarid rangelands. Am. Water Res. Assoc. Abst. 64.

Kustas, W. P., T. J. Schmugge, K. S. Humes, D. C. Goodrich, M. S. Moran, et al. 1992. MONSOON 90 - a study to quantify basin-scale hydrologic fluxes in semi-arid rangelands using remote sensing. EOS Abst. 73:110.

Stannard, D. I., J. H. Blanford, and W. P. Kustas. 1992. Surface energy balances at MONSOON 90. EOS Abst. 73:190.

B. Remote Sensing

Daughtry, C. S. T., M. D. Steven, F. Baret, and V. C. Vanderbilt. 1992. Light capture and phytomass production in sunflower. Agronomy Abstracts 84:14.

Dulaney, W. P., C. S. T. Daughtry and J. R. Irons. 1992. Distinguishing crop residues from soils by derivative analysis of high resolution spectra. Agronomy Abstracts 84:323.

Kustas, W. P., T. J. Schmugge, K. S. Humes, P. C. Doraiswamy, E. Perry, M. S. Moran, and R. T. Pinker. 1992. Remote sensing from plant to watershed in semiarid rangelands. Abstracts, Amer. Water Res. Assoc. p. 64.

McMurtrey, J. E., C. S. T. Daughtry, and E. W. Chappelle. 1992. Evaluation of fluorescence and reflectance sensing techniques for detecting crop residues from soils. Agronomy Abstracts 84:332.

Ritchie, J. C., C. M. Cooper, and F. R. Schiebe. 1992. MSS remote sensing of chlorophyll in sediment dominated lakes. The ASB Bulletin 39:74. Abstract.

C. Systems Research

Haskett, J. D. 1992. Validation study of the model NCSWAP, using data from three Minnesota soils. Abstracts, ASA/CSSA/SSSA Meetings, Minneapolis, MN, Nov. 1-6, 1992.

Reddy, V. R., K. R. Reddy, and B. Acock. 1992. Carbon dioxide enrichment and temperature effects on cotton photosynthesis and respiration. Agronomy Abstracts 84:130.

Reddy, V. R. and B. Acock. 1992. Modeling cotton growth and phenology to temperature. p. 13. Workshop on Crop Simulation, Biological Systems Simulation Group, Corpus Christi, TX, March 23-25, 1992. (Abstract)

D. Biochemical and Physiological Effects

Adamse, P. and S. J. Britz. 1992. Amelioration of UV-B damage under high irradiance: role of photoreceptors. Plant Physiol. 99S:98. Abstract No. 583.

Agrawal, M., G. F. Kramer, E. H. Lee, and R. A. Rowland. 1992. Effect of inverse treatment of day/night temperature on sensitivity of plants to SO_2 or O_3: Changes in polyamine titer. Plant Physiol. 99S:122. Abstract No. 728.

Britz, S. J. and P. Adamse. 1992. Role of photosynthesis in amelioration of UV-B damage. Photosynthesis Research 34S:244.

De Veau, E. J. I. and J. M. Robinson. 1992. Activities of foliar starch synthesis and degradation pathway enzymes in leaves of N_2-fixing compared with NO_3^- and NH_4^+ supplied soybean plants. Plant Physiol. 99S:39. Abstract No. 230.

De Veau, E. J. I. and J. M. Robinson. 1992. Apparent regulation of starch synthesis in leaves of N_2-fixing compared with NO_3^- and NO_4^+ supplied soybean plants. Plant Physiol. 99S:39. Abstract No. 231.

Kramer, G. F., A. Upadhyaya, D. T. Krizek, C. R. Caldwell and R. M. Mirecki. 1992. Influence of spectral quality on UV-B induced changes in biochemical and growth parameters of cucumber. Plant Physiol. 99S:98. Abstract No. 584.

Millard, M. M., O. B. Veisz, D. T. Krizek and M. Line. 1992. Changes in water binding in wheat during cold hardening as studied by NMR and MRI. Plant Physiol. 99S:127. Abstract No. 754.

Pausch, R. C., C. L. Mulchi, E. H. Lee, and J. J. Meisinger. 1992. Use of ^{13}C and ^{15}N isotope labeling to assess O_3 stress on C translocation and N fixation in soybeans grown in open-top chambers. Agronomy Abstracts 84:52.

Robinson, J. M. and K. O. Burke. 1992. Acclimation of soybean leaf CO_2 fixation and linear photosynthetic electron transport to NO_3^- and NH_4^+ limitation. Plant Physiol. 99S:101. Abstract No. 600.

Robinson, J. M. and D. R. Lee. 1992. Acclimation of young soybean plants to high CO_2 level increased the foliar CO_2 compensation point and dark respiration rate. Plant Physiol. 99S:107. Abstract No. 636.

Robinson, J. M. and D. R. Lee. 1992. Response of growth and photosynthetic carbon assimilation in spinach plants to prolonged exposure to elevated CO_2 level. Plant Physiol. 99S:107. Abstract No. 637.

Robinson, J. M. 1992. Starch synthesis in the leaves of CO_2 enriched soybean plants. Plant Physiol. 99S:107. Abstract No. 638.

Rudorff, B. F. T., C. L. Mulchi, E. H. Lee, R. A. Rowland, and R. Pausch. 1992. Photosynthesis and grain yield in winter wheat grown under enriched carbon dioxide and ozone stress. Agronomy Abstracts 84:56.

ARS TEXTRAN (Technology Transfer Automated Retrieval System) Publications

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Modeling Approaches for Predicting Crop Ecosystem Responses to Climate Change

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Submitted to PROCEEDINGS OF FIRST INTERNATIONAL CROP SCIENCE CONGRESS

Interpretive Summary: Climate change is expected to result in combinations of soil, climate, and carbon dioxide (CO_2) concentration that have not been experienced previously. The only realistic way of predicting how crop ecosystems may change, is to simulate future conditions using mechanistic crop and climate models. These models all have known defects so only give a crude indication of what might happen. Also, farmers and agronomists have a long record of adapting crop ecosystems to changing conditions. There is a wide range of genetic material in the available crop species and cultivars that can fit almost any ecological niche. The farmer can also change his management practices such as planting and harvesting date, plant population density, fertilization and irrigation. Looking at the available germplasm from a modeler's point of view, we can identify differences in how phenology and photosynthesis, or dry weight gain, respond to temperature and daylength. We can also identify optimum temperature ranges and extremes which are injurious to crop growth. This information is not readily available and should become part of the specification of every genotype. Given this information, it would be easier to help farmers choose the correct crop cultivar and management practices for any climatic condition.

Technical Abstract: The gradual accumulation of carbon dioxide and other gases in the atmosphere is currently expected to cause climate change. This may result in combinations of soil, climate and carbon dioxide (CO_2) concentration that have not been experienced previously. Crop models are the only realistic tools available for predicting how yields might change. Since the models will be used to extrapolate beyond the range of existing databases they must be mechanistic. They must also mimic crop responses to a wide range of temperatures and to CO_2, especially the long-term response of stomata to elevated CO_2 and the resulting water use by the crop. However, even with adequate models it is not enough to predict crop yields assuming that everything except weather and CO_2 will remain the same. Farmers and agronomists have a long record of adapting crop ecosystems to changing conditions. In some locations, climate change will lengthen the growing season; in others it will shorten the season by virtue of high summer temperatures or drought. More fertilizer will be needed to take full advantage of increased photosynthesis in high CO_2. The farmer will respond by changing planting date, planting density, fertilizer application rate, cultivar and even species. Predictions of crop yield in a future climate must assume that the producer will optimize his management practices for the new environment.

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Amelioration of UV-B Damage Under High Irradiance. I. Role of Photosynthesis

Paulien Adamse & Steven J Britz

Submitted to PHOTOCHEMISTRY PHOTOBIOLOGY

Interpretive Summary: Projected increases in ultraviolet-B radiation (UV-B, 280-315 nm) as a result of stratospheric ozone depletion are a matter of concern; current levels of UV-B can reduce crop growth and yield under some circumstances. Green plants require light for photosynthesis and exhibit several responses that protect against deleterious effects of the UV-B component of solar radiation. We need to understand the relative importance of UV-B-protective mechanisms and the extent to which they adapt to increased UV-B. Sensitivity to UV-B is reduced under high background visible light (e.g., normal daylight). Light may stimulate photosynthesis or affect other photoreceptor systems that modulate responses to UV-B (e.g., screening pigment synthesis, DNA repair). We examined the role of photosynthesis in adaptation to UV-B by treating plants with high chronic UV-B at 2 levels of atmospheric CO_2 while providing high background visible light. Two responses to UV-B were examined, both sensitive to levels of background visible light. Leaf area expansion was inhibited by UV-B at ambient CO_2 but not at high CO_2. Reduced leaf area minimizes interception of UV-B but also decreases photosynthesis per leaf. The results indicate that increased photosynthesis at high CO_2 may limit damage from UV-B. In contrast, elevated CO_2 did not affect a UV-B-induced two-fold increase in the content of UV-absorbing pigments extractable from leaves. Future studies will examine whether light effects on the synthesis of these pigments involves non-photosynthetic photoreceptors. If so, it may be possible to decrease sensitivity to UV-B by amplifying the amount or activity of such photoreceptors. This information should be of interest to plant scientists, breeders, and policy makers.

Technical Abstract: Sensitivity to ultraviolet-B radiation (UV-B, 280-315 nm) is generally reduced when background irradiance is high. We tested the involvement of photosynthesis in the amelioration of UV-B damage by treating plants at high PAR (photosynthetically-active radiation, 400-700 nm; 1000 ìmol m^{-2} s^{-1}) with supplemental UV-B at double ambient levels of "biologically-effective" radiation (18 kJ m^{-2} d^{-1}) and either "ambient" (450 ìmol mol^{-1}) or short term elevated (750 ìmol mol^{-1}) CO_2 levels. Responses to UV-B were assessed by photosynthetic gas exchange, leaf expansion and production of UV-absorbing compounds (presumptive flavonoids) in cultivars of cucumber (*Cucumis sativus* L) previously demonstrated to be relatively sensitive (cv Poinsett) and insensitive (cv Ashley) to UV-B. Except for marginal leaf interveinal chlorosis observed in Poinsett, both cultivars responded similarly. UV-B had little direct effect on leaf photosynthesis, but it did cause reductions in leaf area and corresponding increases in leaf dry matter per area. Increased CO_2 stimulated plant growth and counteracted the effect of UV-B on leaf area, indicating an important role for photosynthesis. In contrast, the accumulation of UV-absorbing flavonoid compounds was enhanced by UV-B exposure but was not affected by CO_2 enrichment.

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Amelioration of UV-B Damage

Steven J Britz, Paulien Adamse & Charles R Caldwell

Submitted to 11 TH INTERNATIONAL CONGRESS ON PHOTOBIOLOGY, SEPT 6-12, 1992, KYOTO, JAPAN and to AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS MEETING, PITTSBURG, PA, AUG 1992

Interpretive Summary:

Technical Abstract: Accumulation of UV-absorbing pigments, presumptive flavonoids, increases at high background photosynthetically-active radiation (PAR). Although enhanced photosynthesis ameliorates some forms of UV-B damage, UV-B-induced accumulation of flavonoids is not affected by elevated atmospheric CO_2. UV-absorbing pigments increase two-fold over 1-2 days in developing leaves exposed to UV-B (double current daily ambient levels for Beltsville) and high PAR (1000 ìmol m^{-2} s^{-1} from amber low pressure sodium lamps [Emax 589 nm]). The rate is accelerated by low levels of supplemental blue light (40 ìmol m^{-2} s^{-1}), suggesting a role for non-photosynthetic photoreceptors. UV-effects on flavonoid accumulation are quantitative rather than qualitative, with increases observed in several compounds. Experiments are underway to identify the major pigments involved and to evaluate their role in protection against UV-B damage.

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Effects of Doubled Atmospheric Carbon Dioxide Concentration on Interactions Between Spodoptera Exigua (Lepidoptera:Noctuidae) Larvae and Two Host Plant Species Outdoors

Frances A Caulfield & James A Bunce

Submitted to ENVIRONMENTAL ENTOMOLOGY

Interpretive Summary: The concentration of carbon dioxide in the atmosphere is rising. Carbon dioxide concentration often affects plant growth rates and alters competition between weeds and crops. Numerous studies in controlled environments have indicated that insects feeding on plants grown at elevated carbon dioxide concentrations often eat more tissue but may have slower growth rates and poorer survival. We have examined the effects of beet armyworm larvae on sugarbeet and pigweed at ambient and twice ambient carbon dioxide concentrations in outdoor chambers. The insect larvae reduced the growth of sugarbeet more than pigweed at ambient carbon dioxide. Elevated carbon dioxide increased the size of the sugarbeet plants such that the same sized insects had no impact on the growth rate of the plants. In contrast to experiments in controlled-environment chambers, our data indicated increased insect survival on sugarbeet at the elevated carbon dioxide concentration. This only occurred if both plants and insects were kept at the elevated concentration. This result has important implications for the way in which experiments should be designed to study plant-insect interactions at elevated carbon dioxide concentrations.

Technical Abstract: Beet armyworm larvae were placed on sugarbeet and pigweed plants in outdoor chambers at either ambient or twice the ambient carbon dioxide concentration. Experiments were performed to determine if larvae reduced plant growth differently at the two carbon dioxide concentrations in either species, and if the insect growth or survival differed with carbon dioxide concentration. Leaf nitrogen, water, starch, and soluble carbohydrate contents were measured to assess leaf quality. Insect feeding significantly reduced plant growth in sugarbeet plants at ambient but not at elevated carbon dioxide, or in pigweed at either carbon dioxide concentration. Larval survival was greater on sugarbeet plants at elevated CO_2 concentration. Increased survival occurred only if both the plants and insects were at elevated carbon dioxide. Leaf quality was only marginally affected by growth at elevated carbon dioxide concentration. The results indicate that in designing experiments to predict effects of elevated atmospheric carbon dioxide concentrations on plant-insect interactions, both plants and insects should be exposed to the experimental carbon dioxide concentrations, as well as to as realistic environmental conditions as possible.

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Effects of Doubled Atmospheric Carbon Dioxide Concentration on the Responses of Leaf Carbon Dioxide and Water Vapor Exchange to Humidity

James A Bunce

Submitted to PLANT PHYSIOLOGY

Interpretive Summary: One of the important effects that a continued rise in atmospheric concentration of carbon dioxide is expected to have on crops is a reduction in stomatal aperture and consequently a lower rate of water loss. Besides having effects on crop physiology, a reduction in rate of evaporation of water from vegetation could also affect global temperature and patterns of precipitation. However, most measurements demonstrating stomatal closure at elevated CO_2 have been made in more humid air than crop leaves normally experience in midday. It was found in this study that in three of four species examined, no effect of elevated carbon dioxide on stomatal aperture occurred when measurements were made in more realistically dry air. This has important consequences for predicting crop water use at elevated atmospheric carbon dioxide concentrations and for predictions of the climatic consequences of the rising atmospheric concentration of carbon dioxide.

Technical Abstract: Experiments were performed to determine if growth at elevated carbon dioxide altered the sensitivity of leaf water vapor conductance and rates of net carbon dioxide exchange to the leaf-to-air difference in the partial pressure of water vapor (VPD). Comparisons were made between plants grown and measured at 350 and 700 ìmol mol^{-1} carbon dioxide for amaranth, soybean and sunflower grown in controlled environment chambers, soybean grown outdoors in pots, and orchard grass grown in field plots. In amaranth, soybean, and orchard grass the sensitivity of conductance to VPD was reduced in plants grown and measured at elevated carbon dioxide. In general, there was little effect of carbon dioxide on conductance when VPD was high. Net carbon dioxide exchange rate was not altered by VPD in amaranth, indicating saturation of photosynthesis for carbon dioxide even at ambient levels in this C_4 species. In sunflower, the net carbon dioxide exchange rate of plants at elevated carbon dioxide was insensitive to VPD, reflecting saturation for carbon dioxide. In contrast, in soybean the sensitivity of net carbon dioxide exchange rate to VPD was not different between carbon dioxide treatments.

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Response of Assimilation and Conductance to Light, CO_2, Temperature and Humidity in Tomato Plants Acclimated to Ambient and Elevated CO_2

Cecilia Stanghellini & James A Bunce

Submitted to ANNALS OF BOTANY

Interpretive Summary: The ongoing carbon dioxide accumulation in the atmosphere could affect both climate and agricultural production. Evaporation of water from crop plants can affect the climate by cooling and humidifying the air, and by altering global patterns of precipitation. Hence the effect of elevated atmospheric carbon dioxide concentrations on crop water use will have to be known in order to correctly forcast the climate. In these experiments leaf water vapor loss rates were measured as functions of short-term changes in light, temperature, humidity and carbon dioxide concentration, in tomato plants grown at current, and twice current atmospheric carbon dioxide concentration. It was found that that while short-term exposure of leaves to elevated concentrations of carbon dioxide decreased their rate of water loss as expected, long-term exposure to the elevated carbon dioxide concentration produced physiological changes in the leaves which offset this effect. It was concluded that crop water use may not decrease at elevated concentrations of atmospheric carbon dioxide.

Technical Abstract: The ongoing carbon dioxide accumulation in the atmosphere could affect both climate and agricultural production. Energy exchange (transpiration, in particular) of vegetated surfaces is able to affect climate, hence the effect of carbon dioxide enrichment on transpiration, as well as on carbon dioxide exchange, will have to be better understood in order to correctly forecast the climate. This paper presents rates of leaf carbon dioxide and water vapor exchange of tomato plants grown at both 350 and 700 ìmol mol^{-1} CO_2. Carbon dioxide exchange rate response curves to both light and short-term CO_2 were quite similar for plants grown at both CO_2. However, water vapor conductance of plants grown at high CO_2 was less sensitive to short term CO_2 variations, and was larger than the conductance of "ambient CO_2" plants both were exposed to high CO_2. Assimilation and conductance increased with temperature over the range 18 to 32 C. The carbon dioxide exchange rate of plants grown in both CO_2 treatments increased at most about 25% from 350 to 700 ìmol mol^{-1} CO_2 at 18 and 25 C, and decreased when exposed to 1000 ìmol mol^{-1} CO_2 at these temperatures. It is concluded that increasing atmospheric CO_2 might not increase photosynthesis by as much as expected and that water use of crops might not decrease.

TEXTRAN

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Stomatal Response to Environment and the Optimization of Carbon Gain with Respect to Water Loss

Cecilia Stranghellini, Basil Acock & James A Bunce

Submitted to AGRICULTURAL AND FOREST METEROLOGY

Interpretive Summary: The ongoing increase in atmospheric carbon dioxide concentration could affect global temperature and precipitation patterns by its tendency to reduce stomatal aperture and the evaporative water loss from vegetation. Models which better predict stomatal resistance in response to environmental variables, including carbon dioxide concentration, are needed for reliable predictions of climate changes in response to increased carbon dioxide concentrations. One current model of stomatal action assumes that plants optimize carbon gain with respect to water loss, and then use photosynthesis models to predict stomatal resistance. We have analyzed the assumptions behind this stomatal model, and found that there is no evidence for a stomatal mechanism which operates on the basis of optimizing carbon gain to water loss. While the model does accurately predict responses to light, temperature and humidity, the response of stomatal resistance to elevated carbon dioxide concentration predicted by this model is opposite to the observed response. We conclude that this model of stomatal resistance will not be adequate when dealing with elevated atmospheric carbon dioxide concentrations.

Technical Abstract: Stomatal resistance influences the balance between carbon gain and water loss. Currently physiologists favor the idea that stomatal responses to environment might be explained by a process whereby the benefits of carbon dioxide uptake are optimized with respect to the costs of water loss. Optimization requires that the balance of costs and benefits be kept constant. Difficulty in quantifying 'costs' and lack of a known stomatal response to the balance of costs and benefits have hampered the application and acceptance of this hypothesis. In the present work, it is shown that the equation presupposed by an optimizing process can be derived simply on the basis of gas exchange principles, without any assumptions about benefits or costs of water loss, or their constancy. It is shown, however, that evolution would tend to render fairly constant the balance of apparent 'costs' and 'benefits'. Experimental results are presented that support some conservativeness of the balance. It is demonstrated that assuming the balance between costs and benefits to be constant does provide accurate predictions of responses of stomatal resistance to light, temperature, and water vapor pressure deficit. However, predictions of stomatal response to elevated carbon dioxide concentration are opposite to those observed. This is taken as evidence supporting the view that evolution, rather than a necessity of the stomatal operating mechanism is to be credited with delivering a conservative value of the balance between carbon gain and water loss.

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Plant Response to Oxidative Stresses V. Bisulfite-Induced Modifications in the Intracellular Thiol Status of Cucumber Coytledons

Abha Upadhyaya & Charles R Caldwell

Submitted to PLANT PHYSIOLOGY

Interpretive Summary: When people become ill it is necessary for their physician to consider their symptoms and identify the disease before he can initiate the appropriate treatment. A similar situation occurs when plants are exposed to environmental factors which result in visible damage or reduced yield. However, identification of the ailment from the plant's visible symptoms is usually too late to prevent irreversible damage. Therefore, it is necessary to develop tests which relate some change in the plant to a given environmental condition. In this report, the effects of sulfur dioxide air pollution on young cucumber plants was investigated. Changes in several compounds were observed which may be characteristic of sulfur dioxide plant damage and indicators of the plant's ability to withstand the air pollutant.

Technical Abstract: The effects of bisulfite and bisulfate on the glutathione (GSH), glutamate (GLU) and aspartate (ASP) levels in cucumber (*Cucumis sativus* L. cv Poinsett) cotyledon discs (5 mm) were determined, using high performance liquid chromatography. In the light, treatment of the cotyledon discs with sodium bisulfite at concentrations up to 2 mM significantly increased tissue GSH levels. Bisulfite in the dark and bisulfate had little effect on the tissue GSH levels. The bisulfite-induced increase in GSH was optimal after 2 h treatment. Measuring tissue viability by the triphenyl tetrazolium chloride (TTC) reduction method, bisulfite rapidly reduced tissue viability in a light-independent process. Bisulfite at low concentrations rapidly reduced the tissue levels of free aspartate and glutamate which was also light independent. Paclobutrazol, a plant protectant, increased the ability of the cotyledon tissue to produce GSH in the presence of bisulfite. Consistent with studies using sulfur dioxide-fumigation of intact plants, the results indicate that changes in both intracellular thiols and free acidic amino acids may be indicators for plants exposed to sulfur dioxide. However, the rapidity of these changes suggest that these bisulfite-induced changes in cellular constituents may represent specific responses to bisulfite and not simply bisulfite impaired photosynthesis, respiration or transpiration.

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Plant Response to Oxidative Stresses VI. Effects of Salicylate, Salicylate Analogues and their Potential Hydroxylation Products on the Intracellular Thiol Status of Cucumber Cotyledons

Charles R Caldwell & Abha Upadhyaya

Submitted to PLANT PHYSIOLOGY

Interpretive Summary: Aspirin and other simple phenolic compounds can reduce the rate of flower wilting and preserve plant cuttings. Aspirin may also serve as a signal when plants are attacked by viruses or fungi, increasing the resistance of the plant to these agents. In this report, results are presented that a simple metabolite of aspirin may be more effective in reducing damage to cucumber plants by the air pollutant, sulfur dioxide, than aspirin.

Technical Abstract: The effects of various simple phenolic acids on the responses of cucumber (*Cucumis sativus* L., cv Poinsett 76) cotyledon tissue to bisulfite were examined. Of all the compounds tested, only 2,5-dihydroxybenzoic acid (25DHBA) significantly increased the bisulfite-induced formation of intracellular reduced glutathione. Furthermore, 25DHBA reduced the bisulfite-induced decreases in free glutamate concentrations and the triphenyl tetrazolium chloride reducing capacity of the cucumber tissue. Considering the concentration of 25DHBA (1 ìM) which resulted in measurable changes in the plant responses to bisulfite and the possibility that 25DHBA could be formed from the reaction of 2HBA and hydroxyl radicals, these results are discussed in terms of 25DHBA serving as a potential signal for excess hydroxyl radical formation in plant tissues.

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Effect of Moisture, Nitrogen Rates and Soil Acidity on Seed Yield and Chemical Composition of Winter Oilseed Rape Cultivars

Z Barszczak, T Barszczak & Charles D Foy

Submitted to JOURNAL OF PLANT NUTRITION

Interpretive Summary: More than half of the arable soils in Poland are highly acidic and sandy in texture. Plants grown on such soils frequently suffer from drought caused by absolute water deficit or by shallow rooting due to aluminum (Al) toxicity in acid subsoils. These conditions also reduce the effectiveness of nitrogen (N) and other fertilizer nutrients. Drought tolerant, Al tolerant and N efficient rape cultivars (cvs.) are needed for such situations. Seven cvs. of winter oilseed rape, *Brassica napus* L., were tested for tolerance to periodic drought (from early budding to the end of flowering) and soil acidity, and for response to N fertilization. Plants were grown in field plots, in open ended ceramic cylinders that were buried to ground level and filled with soil having different acidity levels. Periodic drought was imposed by covering the plots with polythene film. Based on seed yields, rape cvs. differed in tolerance to drought, with Jet Neuf the most tolerant and Bolko the least tolerant. Cultivars also differed in response to N fertilization, with Bolko the most responsive cv. tested. Rapeseed yield was generally reduced by 20%, but cvs. did not differ in acid soil tolerance. Moderate Al toxicity was suspected as the growth limiting factor in acid soil but was not conclusively demonstrated. A higher level of acid soil or Al toxicity will be needed to study the interactions of Al, drought and rapeseed cvs. Reductions in soil moisture or high acidity did not affect the fat and protein contents of rapeseed. Jet Neuf tended to have the highest protein and the lowest fat contents. Jantar was the highest in fat and one of the lowest in protein.

Technical Abstract: 7 cultivars (cvs.) and strains of winter oilseed rape, *Brassica napus* L., were tested for tolerance to drought and soil acidity and for response to nitrogen fertilization. Plants were grown in ceramic cylinders buried to ground level at a field site in Poland. Cylinders contained a gray brown podzolic soil with a medium sandy texture and variable pH due to a history of fertilization. Periodic drought (from early budding to late flowering) was imposed by covering the field plots with polythene film. Rainfall excluded by the film was compensated by watering the non-stressed plants. Based on seed yields, rape cvs. & strains differed in tolerance to drought. 'Jet Neuf' was most tolerant and 'Bolko' least tolerant. Cultivars also differed in response to N fertilization, with Bolko the most responsive cv tested. Rapeseed yields were generally reduced by 20% at a soil pH of 4.2, compared with pH 6.2 (determined in 1 M KCl), but cvs. did not differ significantly in acid soil tolerance. Specific yield-limiting factors in the acid soil were not identified, but mild Al toxicity was suspected. A higher level of acid soil (Al) toxicity will be needed to study Al x drought x rape genotype interactions. Reductions in soil moisture or pH levels didn't affect the fat and protein contents of rapeseed. Variations in fat and protein contents observed were due largely to cv. differences. Jet Neuf had the highest protein and the lowest fat content. 'Jantar' was the highest in fat content and one of the lowest in protein content.

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Drought Avoidance in Peanuts: Epicuticular Wax Loads and Root Growth in Compacted Soil

Robert K Howell

Submitted to PEANUT SCIENCE

Interpretive Summary: Drought adversely affects yields and quality of peanut seed in many parts of the world. Plant traits that are heritable enable plant geneticists to develop peanuts that resist drought. The natural wax coatings on leaves and the sizes of plant root systems are heritable traits. These were investigated in peanut genetic lines to determine if one or both traits would be responsible for drought resistance. The results of this study show a stronger relationship between drought resistance and wax coatings than between root growth and drought resistance. The findings indicate to plant geneticists that increased wax layers will be a useful component for improving peanut resistance to drought and increasing yields.

Technical Abstract: Drought adversely affects yields and quality of peanut (*Arachis hypogaea* L.) seeds in many parts of the world. Plant characteristics that enable peanut plants to be productive in arid areas need to be identified to determine if the traits are heritable and can be used by geneticists to improve drought tolerance. Epicuticular wax and rooting depth are two traits that contribute to plant drought avoidance. Ten peanut genotypes, five drought tolerant and five drought resistant were exposed to drought 30 days after planting in a greenhouse. Quantities of wax isolated from peanut leaves ranged from 37-47 ìg cm^2. Drought caused significant increases in wax loads in all genotypes, but the five drought tolerant entries had a mean of 14% more wax than the sensitive ones. Two genotypes, NC18233, drought tolerant, and VA8433, drought sensitive, were selected for other studies. Leaflet water losses for VA8433 and for NC1823 were significantly different and were 18% and 14%, respectively, after three hours. Root dry weights for the two genotypes were determined after growth for 30 days above compacted soil of three penetrometer strengths. Contrary to what might be expected, mean root dry weights of VA8433 were significantly heavier (12.5 mg) than roots of NC18233 (9.1 mg). Quantities of roots isolated from soil of each compacted strength were greater for VA8433 than for NC18233. Drought resistance in this study was strongly associated with wax accumulation and resistance to leaf water loss but not with root weight.

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Drought Resistant Plants Identified by Temperature Induced Changes in Root/Seed Weight Ratios

Robert K Howell

Submitted to AMERICAN SOCIETY OF AGRONOMY MEETING IN NOVEMBER, 1992

Interpretive Summary:

Technical Abstract: Techniques that identify drought resistant germplasm are needed to produce plants tolerant to environmental stress. Germplasm that is resistant to heat is often resistant to drought. We tested the hypothesis that young seedlings that have a larger ratio of root growth to residual seed weight at elevated temperatures should be more tolerant of drought than those with a lesser ratio. Peanut, *Arachis hypogaea* L., seeds, from 200 lines, were germinated for 5 days at 27, 32, or 37 C. Roots were separated from seed, both were dried and ratios determined. At either 32 or 37 C, germplasm could be easily identified as having high or low ratios. Five genotypes with high and five with low ratios were evaluated in field plots or in pots of soil in a greenhouse. Plant wilting in response to drought in field plots during three years correlated well ($r = 0.92$) with ratios of selected germplasm. This technique is reasonably inexpensive and appears to be suitable to identify drought resistant genotypes in their early growth stage.

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Control of Polyamine Accumulation in Plants Under Stress

George F Kramer & Frank J Turano

Submitted to BARC POSTER DAY, MARCH 10, 1991, BELTSVILLE, MD

Interpretive Summary:

Technical Abstract: Increased levels of ammonia have been observed in tissues from environmentally stressed plants. Several laboratories have proposed that this ammonia is ultimately detoxified by incorporation of the nitrogen into polyamines. Ammonia is reassimilated into glutamine and then the nitrogen is transferred to glutamate. Once in the urea cycle, nitrogen can accumulate into polyamines via two routes; 1) by the decarboxylation of ornithine to form putrescine or 2) by the decarboxylation of arginine to form agmatine which is a precursor of putrescine. These reactions are regulated by ornithine decarboxylase (ODC) and arginine decarboxylase (ADC), respectively. We have developed a detached leaf system in soybean to test the effects of various nitrogen and carbon compounds on polyamine accumulation. Leaves were "fed" various nitrogen and carbon compounds separately or in combination, polyamine levels were determined and compared against buffered controls. Leaves incubated in ammonia, glutamine, arginine, and citrulline showed significant increases in putrescine and spermidine levels, while leaves fed glucose, sucrose or TCA intermediates did not accumulate polyamines. Leaves fed both nitrogen and carbon compounds had polyamine levels similar to controls. In addition, we used inhibitors of ADC and ODC to determine their role in the accumulation of polyamines. The data suggest that there is a strong interaction between carbon and nitrogen availability on polyamine accumulation, and that the accumulation of polyamines observed is due solely to ADC activity.

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Book Review of Climatic Change and Plant Genetic Resources by M.T. Jackson, B. V. Ford-Lloyd, and M.L. Parry (Eds). Belhaven Press, London, New York.

Donald T Krizek

Submitted to DIVERSITY

Interpretive Summary:

Technical Abstract: This book review was prepared for the journal Diversity. It describes the contents of a book entitled Climatic Change and Plant Genetic Resources. The book was edited by Michael Jackson, Brian Ford-Lloyd and Martin Perry and contains the Proceedings of the Second International Workshop on Plant Genetics Research, held in England in 1989. Recent increases in carbon dioxide, chlorofluorocarbons (CFC's), methane, and other trace gases have focused increased attention on the prospect of global climate change. Whether plant genetic resources are sufficient to cope with projected increases in global warming, UV-B radiation, and other projected climatic changes is one of the key questions posed in the book. The book contains information on a range of topics relating to climatic change and germplasm resources. This includes biochemical responses to increased CO_2, genetic vulnerability of crop species, ecological effects of climate change on the distribution and composition of British flora, quantitative relations between temperature and crop development, impact of global climatic change on genetic resources of forest trees and effects of severe drought on genetic resources in W. Asia and N. Africa. Recommendations are given for conserving and utilizing plant genetic resources. The authors stress the need to maintain germplasm collections to preserve genetic diversity of native and cultivated species. They suggest that because of the genetic diversity of existing germplasm, genetic resources, if properly conserved, can meet the challenges imposed by global change. Because of the uncertainty of GCM's and the difficulty of predicting how climatic change will affect crops in any given geographic area, it may be unrealistic to expect plant breeders to consider making drastic changes in their current breeding objectives.

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Effects of Spectral Quality and PAR on UV-B Response of Soybean

Donald T Krizek, Roman M Mirecki & George F Kramer

Submitted to INTL CONGRESS ON PHOTOBIOLOGY, KYOTO, JAPAN, SEPT 7-12, 1992

Interpretive Summary:

Technical Abstract: UV-B-sensitive (Essex) and -insensitive (Williams) cultivars of soybean (*Glycine max* (L.) Merr.) were grown for three weeks from seeding in growth chambers at photosynthetically active radiation (PAR) levels of 300 or 600 ìmol m^2 s^{-1} provided by either red- and far-red-deficient (metal halide, MH) or blue-deficient (high pressure sodium deluxe, HPS/DX) lamps and either 0, 9.9 (low), or 12 (high) kJ m^2 d^{-1} of biologically effective UV (equivalent to no UV, or 10 or 20% stratospheric ozone depletion). Overall, plants were larger and had more leaf area and biomass of tops under HPS/DX than under MH lamps. Likewise, plants grown at 600 ìmol m^2 s^{-1} had greater leaf area and biomass of tops than those grown at 300 ìmol m^2 s^{-1}. High UV-B reduced height, fresh and dry weights, internode length, and total leaf area, while low UV-B increased the number and leaf area of the lateral shoots. Spectral quality or PAR alone had little effect on UV-B sensitivity. At low PAR, UV-B injury was greater in Essex under HPS/DX than under MH lamps. Leaf growth was inhibited in both cultivars at high UV-B irradiance, but was stimulated in Essex at low UV-B irradiance. Dry weight and internode length in Williams were decreased by both UV levels, while in Essex low UV-B irradiance had no effect.

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Influence of Inverse Day/Night Temperature on Ozone Sensitivity and Selected Morphological and Physiological Responses of Cucumber

Madhoolika Agrawal, Donald Krizek, Shashi Agrawal, George Kramer, Edward Lee, Roman Mirecki & Randy Rowland

Submitted to JOURNAL OF AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE

Interpretive Summary: Because of growing concern about water quality, greenhouse growers have been looking at non-chemical methods of controlling growth of ornamental plants. Recent studies have shown that the use of inverse day/night (D/N) temperature is highly effective as a means of regulating stem elongation and providing protection against ozone pollution. The present study was conducted to determine whether similar effects could be obtained in cucumber. Plants were grown from seed in a growth chamber at 28/18C (normal) or 18/28C (inverse) day/night (D/N) temperature for 24 days prior to ozone fumigation (3 h at 0.5 ìmol mol^{-1}). Plants of both 'Ashley' and 'Poinsett' cucumber grown under inverse D/N temperature showed a significant reduction in height, node number, fresh weight, dry weight, and leaf area as compared to those grown under normal D/N temperature. Photosynthetic (Pn) rate, chlorophyll concentration, and variable chlorophyll fluorescence (Fv) were lower and ozone injury and polyamine levels were greater at 18/28C than at 28/18C D/N temperature. Ozone fumigation generally increased the concentration of polyamines (known to be important in providing protection against air pollutants and other oxidative stresses) and reduced the Pn rate, stomatal conductance, and chlorophyll fluorescence (Fv and Fv/Fo). Since global warming is currently expected to have a greater effect on night temperature than day temperature, these findings should be of interest to policy makers and other scientists involved in research on climate change.

Technical Abstract: *Cucumis sativus* L. (cultivars 'Poinsett' and 'Ashley') plants were grown from seed in a growth chamber at 28/18C (normal) or 18/28C (inverse) day/night (D/N) temperature with a 12 h photoperiod for 24 days prior to ozone fumigation (3 h at 0.5 ìmol mol^{-1}). Plants of both cucumber cultivars grown under inverse D/N temperature showed a significant reduction in height, node number, fresh weight, dry weight, and leaf area as compared to those grown under normal D/N temperature. Photosynthetic (Pn) rate, chlorophyll concentration, and variable chlorophyll fluorescence (Fv) were lower and ozone injury and polyamine levels were greater at 18/28C than at 28/18C D/N temperature. Ozone fumigation generally increased the concentration of polyamines and reduced the Pn rate, stomatal conductance, and chlorophyll fluorescence (Fv and Fv/Fo). Overall, 'Poinsett' had a higher specific leaf mass and generally a higher concentration of chlorophyll a and polyamines than did 'Ashley' but showed no difference in ozone injury, growth response, Pn rate, or stomatal conductance.

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Influence of Spectral Quality on UV-B Induced Changes in Biochemical and Growth Responses of Cucumber

Donald Krizek, George Kramer, Abha Upadhyaya & Roman Mirecki

Submitted to PHYSIOLOGIA PLANTARUM

Interpretive Summary: Recent evidence of an acceleration in the rate of stratospheric ozone depletion indicate that increased UV-B radiation may have an adverse effect on crop plants. In order to mitigate possible losses in yield, it is important to investigate how varying environmental conditions can modulate UV-B sensitivity and to characterize existing defense mechanisms in higher plants. We have initiated such studies by comparing selected biochemical and growth responses of sensitive and insensitive cultivars of cucumber to increased UV-B under different sources and levels of visible light (PAR). Plants were grown under 300 and 600 ìmol m^2 s^{-1} of PAR provided by red- and far-red-deficient metal halide (MH) or blue-deficient high pressure sodium/deluxe (HPS/DX) lamps. Plants were irradiated 15 days from time of seeding for 6 hr per day to simulate 40% ozone depletion. UV-B induced-chlorosis was more pronounced under HPS/DX than under MH lamps, in Poinsett than in Ashley cucumber, and in lower leaves than in upper ones. One of the most pronounced effects of increased UV-B was a 20 to 75% increase in phenylalanine ammonia-lyase (PAL) activity in both cultivars and under both PAR sources. This finding should be of interest to breeders and molecular biologists in view of the well-known role of PAL in the formation of protective compounds in the upper surface of the leaf known as flavonoids and the possibility of engineering improved genotypes for UV tolerance.

Technical Abstract: UV-B sensitive (Poinsett) and insensitive (Ashley) cultivars of cucumber were grown in growth chambers at 600 ìmol m^2 s^{-1} of photosynthetically active radiation (PAR) provided by red- and far-red-deficient metal halide (MH) or blue-deficient high pressure sodium/deluxe (HPS/DX) lamps. Plants were irradiated 15 days from time of seeding for 6 hr per day under 18.2 kJ m^{-2} of biologically effective UV-B. UV-B induced-chlorosis was more pronounced under HPS/DX than under MH lamps, in Poinsett than in Ashley cucumber, and in lower leaves than in upper ones. One of the most pronounced effects of UV-B was a 20 to 75% increase in phenylalanine ammonia-lyase (PAL) activity in both cultivars and under both PAR sources. These findings are of interest in view of the well-known role of PAL in phenylpropanoid metabolism and previously observed increase in flavonoids in UV-B irradiated cucumber seedlings. UV-B increased total polyamines as a result of increases in spermidine. Levels of conjugated polyamines (PA) were less than 10% of the total PA pool and showed no consistent response to UV-B. Catalase and superoxide dismutase also varied greatly in their response to UV-B.

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Diverse Susceptibility of Young Conifers in Response to Sulfur Dioxide, Ozone, and SO_2 Plus 0_3

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Submitted to PLANT DISEASE

Interpretive Summary: An increasing number of forest ecosystems in North America and Europe are suffering from decline problems that have been related directly or indirectly to air pollution. At the present time, no single factor has been clearly identified as the cause of recent forest decline. Before we can correlate environmental data to forest productivity, we must have some knowledge of the quality of data available, and know how these conifers will respond to gaseous pollutants. In this report, six geographic sources of Douglas fir and seven other species of conifers were screened for their susceptibility to gaseous pollutants. From research results it appears that atmospheric pollutants could represent a major factor in the complex development of forest decline.

Technical Abstract: Specimens of six geographic sources of Douglas fir (*Pseudotsuga menziesii*) and seven other species of conifers, when in active growth, were exposed for six-hour treatments of: (1) 2.0 ìmol mol^{-1} of sulfur dioxide (SO_2), (2) 0.9 ìmol mol^{-1} of O_3, and (3) a mixed gas of 0.55 ìmol mol^{-1} of O_3 plus 1.5 ìmol mol^{-1} of SO_2. Overall injury level and percentage of leaf-length injured were scored at about seven days after each treatment. With respect to SO_2, the most susceptible sources of Douglas fir were from Arizona, New Mexico, and Colorado (96% to 100% of needle-lengths injured). A British Columbia source was less susceptible. Among other conifers, the most susceptible was Japanese larch (*Larix leptolepis*), followed by loblolly pine, red pine (*Pinus resinosa*), and Eastern white pine (*Pinus strobus*). The least susceptible were spruce (*Picea*) species; blue spruce (*Picea pungens*) and Norway spruce (*P. abies*) had only leaf-tips (about 14% of leaf-length) injured, and white spruce (*P. glauca*) showed no signs of any injury. The susceptibility to O_3 showed no correlation to the susceptibility to SO_2. The mixed gas of O_3 + SO_2 (both less concentrated) caused no significant increase in injuries. The most sensitive were Douglas fir from Colorado, red pine and loblolly pine. After SO_2 treatment, spruce species were the least injured. Eastern white pine from Maryland was more injured than a source from North Carolina's seed orchard. The injury caused by the mixed pollutants was significantly correlated with the injury caused by SO_2 alone, but showed no correlation to the injury due to O_3 alone.

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Effects of Enriched Carbon Dioxide and Ozone Stress on Canopy Reflectance and Grain Yield in Winter Wheat

B F T Rudorff, Charles L Mulchi, Craig S T Daughtry & Edward H Lee

Submitted to PROCEEDINGS OF '92 ANNUAL MEETING OF THE AMERICAN SOCIETY OF PHOTOGRAMETRY AND REMOTING SENSING/AMERICAN CONGRESS OF SURVEYING AND MAPPING GLOBAL CHANGE, AUG 3-8, '92 WASH. DC

Interpretive Summary: In view of uncertainties concerning the extent and impact of global warming, we conducted an experiment at the USDA Beltsville Agricultural Research Center to evaluate the combined effect of carbon dioxide (CO_2) and ozone (O_3) grain yields in winter wheat. Open-top field chambers and multispectral remote sensing techniques were used to investigate the response. Photosynthesis and canopy leaf area index reflectance measurements were taken in an effort to evaluate the potential of remote sensing data to estimate losses in crop productivity due to air pollution. Effects of CO_2 and O_3 individually were consistent with those reported previously. The CO_2 and O_3 interactions observed were generally consistent with a reduction of O_3 injury by increased CO_2. The significance of these studies was to incorporate the remote sensing technology to detect and assess the impact of atmospheric gases as it related to global climate changes. We would expect the research to be utilized by scientific community, government and agricultural chemical companies as well.

Technical Abstract: An experiment was conducted during the spring of 1991 at the USDA Beltsville Agricultural Research Center to evaluate the combined effect of carbon dioxide (CO_2) and ozone (O_3) on remotely sensed multispectral canopy reflectance and grain yields in winter wheat (*Triticum aestivum* L.). Plants were grown full-season (after dormancy to harvest) in the field in open-top chambers supplied with charcoal-filtered air (CF) or CF+40 nmol mol^{-1} O_3 above ambient O_3 concentration (7 h day^{-1}, 5 days week^{-1}) and a CO_2 concentration of ambient CO_2 (350 ìmol mol^{-1}) or +150 ìmol mol^{-1} CO_2 (12 h day^{-1}). Multispectral canopy reflectance was measured weekly from the early vegetative stages until maturation. The normalized difference vegetation index (ND), which was used to estimate the fraction of absorbed photosynthetically active radiation (FAPAR) and the absorbed PAR (APAR). Tests of main effect of O_3 on ND was significant from the third week of treatment until maturation. The main effect of CO_2 on ND was not significant at any measurement dates. However, main effects of CO_2 and O_3 were significant for both biomass and grain yield. Accumulated APAR over the growing season was significantly lower for the high-O_3 treatments. Plants grown under CO_2 enriched air had significantly higher conversion efficiency (E) of APAR into above ground dry biomass than plants grown under ambient CO_2 air. Conversion efficiency was significantly lower for the O_3 treatment with ambient CO_2 air. High-O_3 treatments had about 15% less grain weight than low-O_3 treatments. Enriched CO_2 treatments had about 25% more grain weight than ambient CO_2 treatments.

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Effect of Reversal of Day/Night Temperatures on Sensitivity of Plants to SO_2 or 0_3: Changes in Polyamine Titer

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Submitted to PHYSIOLOGIA PLANATARUM

Interpretive Summary: Air pollutants have long been known to cause physiological impairment and growth reduction in plants. Antioxidants such as superoxide dismutase, catalase, ascorbic acid, glutathione and polyamines may be involved in plant adaptive mechanisms against oxidative damage caused by air pollutants and other related environmental stress. Changes in antioxidants could lead to altered crop yields by changing plant susceptibility to air pollutants. The present study supports the view that polyamine accumulation is one of the metabolic response of plants to air pollution. Pretreating bean plants at 18/28C day/night (D/N) temperatures prior to ozone and sulfur dioxide fumigation resulted in a suppression of air pollutant-induced necrosis concomitant with an accumulation of polyamines. This result supports the previously described antiozonant effect of polyamines in plants. The plants which produce more polyamines are more resistant to the development of sulfur dioxide or ozone induced visible injury. The accumulation of high levels of polyamines in plants pretreated at a 18/28C D/N temperature suggests that a reversal of D/N temperature has elevated the antioxidant capacity of these plants which in turn protects the plants against visible injury damage. This accumulation of polyamines was related to the ability of plants to inhibit senescence related lipid peroxidation.

Technical Abstract: Snapbean (*Phaseolus vulgaris* cv. Bush Blue Lake 290) plants were pretreated for two weeks at 28/18 C and 18/28 C day/night temperature regimes and then exposed to either 0.30 ìmol mol^{-1} O_3 or 0.5 ìmol mol^{-1} SO_2 for 3 h. The effects of the reversal of day and night (D/N) temperatures on plant sensitivity to acute O_3 or SO_2 concentrations were evaluated in terms of changes in free polyamine titer. The levels of putrescine (Put) and spermidine (Spd) increased significantly in response to the low day and high night temperature regime. O_3 and SO_2 exposures also increased the Put, Spd and spermine (Spn) levels in leaves from both 28/18 C and 18/28 C D/N temperature regimes at different time intervals after fumigation. Put content increased maximally 48 h after exposure to either O_3 or SO_2 in both 28/18 C and 18/28 C D/N temperature-treatment, whereas maximum increases in Spd were observed just after exposure in 18/28 C D/N temperature-treatment and after 24 h in 28/18 C D/N temperature-treatment plants. Spn levels were maximum at 24 h after exposure and were increased to a greater extent in response to SO_2 than to O_3 treatment. Pre-treatment of plants at a 18/28 C D/N temperature resulted in a greater increase in free polyamines as compared to those pretreated at a 28/18 C D/N temperature. Pre-treatment of plants at a 18/28 C D/N temperature also inhibited the development of O_3 and SO_2 induced visible injuries.

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Photosynthesis and Grain Yield in Winter Wheat Grown Under Enriched Carbon Dioxide and Ozone Stress

Bernardo F Rudorff, Charles L Mulchi, Edward H Lee, Randy A Rowland & Roman C Pausch

Submitted to 1992 ANNUAL MEETING OF AGRONOMY SOCIETY (ASA) MEETING

Interpretive Summary:

Technical Abstract: Field studies were conducted at USDA-ARS BARC using open-top chambers to evaluate the combined effects of ozone (O_3) and carbon dioxide (CO_2) on photosynthesis (PS) and grain yield in winter wheat (Triticum aestivum L.). Plants were grown under charcoal-filtered (CF) air or CF + 40 nmol mol^{-1} O_3 above ambient O_3 concentration (7 h day^{-1}, 5 days $week^{-1}$) in factorial combination with CO_2 (12 h day^{-1}, 5 days $week^{-1}$) at ambient (350 ìmol mol^{-1}) or elevated (500 ìmol mol^{-1}) concentrations. PS was measured on fully expanded leaves on 6 dates at five different growth stages. Grain yield was obtained after harvest at physiological maturity. Tests of main effects of CO_2 and O_3 on PS data averaged over the six dates were highly significant. High-O_3 treatments had about 10% lower PS rates than low-O_3 treatments. Enriched CO_2 treatments had about 15% more PS than ambient CO_2 treatments. The interactive effect of O_3 and CO_2 on PS was not significant. Tests of main effects of O_3 and CO_2 grain yields were highly significant. High-O_3 treatments had about 15% less grain weight than low-O_3 treatments. Enriched CO_2 treatments had about 25% more grain weight than ambient CO_2 treatments. Changes observed in grain yields were consistent with the PS results suggesting that the 500 ìmol mol^{-1} CO_2 treatment had a protective role against the damage caused by O_3.

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Use of ^{13}C and ^{15}N Labeling to Assess Ozone Stress on C Translocation and N Fixation in Soybeans Grown in Open-Top Chambers

Roman C Pausch, Charles L Mulchi & Edward H Lee

Submitted to 1992 ANNUAL MEETING OF AGRONOMY SOCIETY (ASA) MEETING

Interpretive Summary:

Technical Abstract: Stable isotopes of carbon (^{13}C) and nitrogen (^{15}N) were used to label ozone (O_3) stressed soybean plants grown in open-top chambers during three growing seasons in Maryland. ^{13}C labeled CO_2 and ^{15}N labeled soil were incorporated into plants by leaf and root uptake, respectively. Data were collected from plant organs (i.e. leaves, stems, roots, nodules, and pods) at full bloom and at late pod fill-beginning seed. Changes in labeling of ^{13}C and ^{15}N were used to determine changes in C translocation and N fixation. Generally, increased O_3 resulted in deceased N fixed/soil N ratio, and decreased translocation of ^{13}C from leaves to roots, nodules, and pods. These responses occurred usually without significantly affecting total ^{13}C uptake per plant, or the N fixed & total N per plant. The results suggest that O_3 stress may have direct effect on photosynthate translocation from source (leaves) to sinks (roots, nodules, and pods), thus limiting N-fixation of nodules.

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Use of ^{13}C Isotope Labeling to Assess O_3 Stress on Carbon Translocation in Soybeans Grown in Open-Top Chambers

Roman C Pausch, Charles L Mulchi & Edward H Lee

Submitted to 3RD INTERNATIONAL SYMPOSIUM ON GASEOUS POLLUTANT & PLANT METABOLISM AT VPI

Interpretive Summary:

Technical Abstract: Ozone effects on the growth and/yield of *Glycine max* are well known, however the mechanism of action is still not well understood. Carbon uptake and translocation are believed to be involved, but photosynthate translocation response to O_3 in soybean has been little studied. Investigations were conducted using ^{13}C isotope labeling of soybeans to determine uptake and translocation effects of O_3. Plants were grown in pots in open-top chambers equipped with carbon filters and exposed to one of three ozone treatments resulting in 7h mean O_3 concentrations of 26, 46, and 71 ppb. At full bloom (R2) and beginning seed (R5), plants were removed from the field, placed in growth chambers, and labeled with $^{13}CO_2$ for 10h. Plant material was harvested at 10h and 52h, for later C analysis. Net relative translocation values were determined for leaves, stems, roots, nodules, and pods over the 42h period using data derived from atom % ^{13}C. Translocation was linearly related to increased O_3 for leaves, stem, root, and pods. Regression coefficient values ranged from R=0.82 to 0.99. At R2, O_3 decreased translocation out of leaves, and into roots. At R5, O_3 decreased translocation out of leaves and roots, and into the pods. These observations occurred without any concomitant significant differences in initial ^{13}C uptake.

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Wheat Kernel Growth Characteristics During Exposure to Chronic Ozone Pollution

Leon H Slaughter, Charles L Mulchi & Edward H Lee

Submitted to ENVIRONMENTAL POLLUTION

Interpretive Summary: Much of the Northeast United States experiences elevated ozone (O_3) levels during the growing season of winter wheat. Chronic exposure to O_3 air pollution can reduce yield in wheat; however, little is known concerning the effects of O_3 stress on grain development. Ozone pollution may alter grain growth such that yield is reduced. Since little information is available concerning the effects of O_3 on the components of reproductive growth and development in wheat, the objectives of this study were to determine the effects of short duration chronic O_3 exposure on grain growth components of winter wheat and to examine grain growth rate and duration of grain fill among two wheat genotypes during exposure to O_3 pollution. We previously reported a 10% yield reduction in field grown winter wheat following exposure to nonfiltered (NF) air plus 80 nmol mol^{-1} O_3 during flowering and grain fill. This study shows that some grain growth components are altered when wheat is grown under O_3 pollution (above NF + 40 nmol mol^{-1}) of a relatively short duration (4 h per day). These data suggest that decreased economic yield associated with chronic O_3 exposure is primarily the result of decreased grain growth rate.

Technical Abstract: A field study was conducted at USDA-BARC to investigate the effects of chronic O_3 exposure on kernel growth components of two soft red winter wheat genotypes (Severn and MD5518308). Five air quality treatments including charcoal-filtered air (CF), nonfiltered air (NF), NF + 20, NF + 40, and NF + 80 nmol O_3 mol^{-1} air were applied 4 h d^{-1}, 5 d wk^{-1} between 1000 and 1400 (EST), from 10 d preanthesis through maturity. In the case of the NF treatments, O_3 was added to existing ambient O_3 levels. Spike samples were collected 16, 20, 24, 28 and 32 days after anthesis (DAA). Linear and quadratic equations were fitted to kernel weight data to estimate kernel growth rate (KGR) and kernel fill duration (KFD). Effective filling period (EFP) and assimilate utilization (AU) were also determined. Rates of growth for individual kernels were 0.74 mg d^{-1} and 1.07 mg d^{-1} for the NF + 80 and CF treatments, respectively. The NF + 80 nmol^{-1} O_3 treatment significantly reduced KGR and AU compared to the CF treatment. Severn had a significantly longer KFD than MD5518308, but O_3 exposure had no effect on KFD. Linear relationships between O_3 exposure and kernel weight suggest that O_3 effects on kernel weight begin soon after anthesis in MD5518308 and in Severn O_3 has a greater effect on kernel weight during the later stages of kernel development. These data suggest that decreased economic yield associated with chronic O_3 exposure is primarily the result of decreased KGR.

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Areal Extent of Seasonal Snow Cover in a Changed Climate

Albert Rango & Jaroslav Martinec

Submitted to CLIMATIC CHANGE

Interpretive Summary: When climate change scenarios are presented, they commonly deal with two environmental variables, namely, temperature and precipitation. In mountainous areas, the change of snow cover extent is of great importance, but little information is available on how the extent of snow will respond to climate change. In this paper, a method for calculating whether a given climate change scenario will speed up or slow down the seasonal decrease of snow covered area is presented. A computer algorithm has been developed so that the response of snow cover can be calculated automatically. This method can be used to generate snow cover in a new climate for snowmelt runoff models, to provide input to climate models that require knowledge of land area covered by snow, and to provide data for estimating ecosystem responses to changing snow cover. The method could be used by hydrologists, climatologists, and ecologists in various Federal and state agencies.

Technical Abstract: In mountain snow basins, a change of climate will likely cause a change in the basin snow cover extent. A procedure for evaluating whether a given climate change scenario will speed up or slow down the seasonal decrease of snow covered area is outlined with hypothetical examples for a simple basin. This procedure has two main purposes. First, it can be used to generate snow covered area data in a new climate for input to runoff models such as the Snowmelt-Runoff Model (SRM). Second, it can be used to provide input to climate models that require knowledge of the land area covered by snow at a given time. A computer program is now operational for use on real basins as demonstrated on the Rio Grande basin in Colorado.

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Rainfall-Snowmelt Peaks in a Warmer Climate

Jaroslav Martinec, Albert Rango & Ralph Roberts

Submitted to PROCEEDINGS OF THE SYMPOSIUM ON MANAGING WATER RESOURCES DURING GLOBAL CHANGE

Interpretive Summary: Many snowmelt-runoff models have difficulty in handling simulation of combined rainfall and snowmelt runoff peaks. Further, as climate changes, warmer temperatures will cause more of these type events to occur. If models are used to estimate the effects of climate change, they must be prepared for more of these combined runoff events. A new algorithm was developed for the Snowmelt-Runoff Model (SRM) to handle the large rainfall events that occur during active snowmelt. This new algorithm provided better simulation results on the Illecillewaet basin in British Columbia. In a warmer climate, SRM will automatically calculate rain versus snow events and then apply the new algorithm under pre-established threshold conditions. This new algorithm and SRM will be especially valuable for water managers, both public and private, as they attempt to cope with the growing demand for them to predict how a basin will respond to climate change.

Technical Abstract: Dangerous floods can occur when rainfall-runoff peaks are superimposed on already high runoff levels resulting from snowmelt. In mountain basins, precipitation during the snowmelt season is partly rain and partly snow. If the climate becomes warmer in the future, some of today's snowfall will become rainfall. Consequently, runoff peaks from combined snowmelt and rainfall may become more frequent. It is necessary to pay more attention to such events when modeling the runoff. Rainstorms are concentrated in short periods in contrast to the more evenly distributed snowmelt. Therefore, the basin response is quicker, and the runoff peaks are more difficult to forecast. Examples from the Illecillewaet basin in the Canadian Rocky Mountains (1155 km^2, 509-3150 m a.s.l.) illustrate difficulties in simulating rainfall runoff peaks and adaption of the Snowmelt Runff Model (SRM) to handle such events. A rainfall peak from a daily precipitation of 7.11 cm is better simulated if the recession coefficient is temporarily lowered by a special algorithm. The threshold for activating this algorithm is normally 6 cm of daily rainfall, but it can be changed, if necessary. For example, two minor peaks from rainfalls of 1.88 cm and 1.01 cm, respectively, have been better simulated by lowering the threshold. As another new development, a SRM capability is outlined that will simulate runoff patterns in mountain basins for any desired climate scenario with changed temperatures and precipitation. This procedure is illustrated by a hypothetical increase of temperatures by 3 degrees C and the resulting new runoff distribution in the summer half year.

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User's Manual for the Snowmelt Runoff Model (SRM)
(Updated Edition 1992, Version 3.2)

J Martinec, A Rango & R Roberts

Submitted to HYDROLOGY LABORATORY TECHNICAL REPORT

Interpretive Summary:

Technical Abstract: This new edition of the User's Manual and new personal computer (PC) program Version 3.2) for the Snowmelt Runoff Model (SRM) feature in particular: (1) The possibility of inputting separate climate station data for each elevation zone; (2) Automatic printout of modified depletion curves of the snow coverage for day-to-day and seasonal runoff forecasts; (3) More guidance for selection of model parameters and for eliminating errors; (4) Improved handling of rainfall peaks; and (5) Assessment of the impact of a changed climate on the snow cover and snowmelt runoff. So far, about 100 diskettes with PC program Version 1 and 2.01 for SRM have been distributed to users in different parts of the world. This manual corresponds to the more recent improved Versions 3.0, 3.1, 3.11, and 3.2 (which is now available).

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Carbon Dioxide and Temperature Effects on Cotton Leaf Growth and Development

Vangimalla R Reddy, K R Reddy & Basil Acock

Submitted to AGRONOMY JOURNAL

Interpretive Summary: The predicted increase in atmospheric carbon dioxide concentration and surface air temperature could have a significant effect on the growth and development of major agricultural crops. This study was conducted to evaluate the effects of ambient and doubling of carbon dioxide at a range of temperatures on initiation and growth of cotton leaves. This experiment was conducted by growing cotton plants in plant growth chambers with temperature and carbon dioxide as controlled variables. The air temperatures in the growth chambers were maintained at 15/7, 20/12, 25/17, 30/22, and 35/27°C. The carbon dioxide concentrations were maintained at 350 and 700 ìmol mol^{-1} for each temperature utilizing 10 controlled environment cabinets. Temperature and carbon dioxide had significant effect on growth and final size of the cotton leaves. Leaf initiation on the main stem is primarily temperature dependent and not limited by carbon supply in ambient CO_2. Temperature had a significant effect on the final size of the leaves, and duration and rate of leaf growth, while CO_2 increased final leaf size and rate of leaf expansion. The rate of leaf expansion increased with temperature up to 26.6°C, and declined at higher temperature in both CO_2 levels. Duration of leaf expansion is not influenced by carbon supply, but strongly influenced by temperature. Carbon dioxide increased total leaf area due to small increases in individual leaf size and also due to the production of more nodes on fruiting and vegetative branches.

Technical Abstract: The current increase in atmospheric CO_2 concentration and the predicted increase in global surface air temperature have stimulated the need for a database on the response of agricultural crops to CO_2 and temperature in various combinations. The objectives of this study were to evaluate the effects of ambient and doubled CO_2 at a range of temperatures on leaf initiation rates, expansion rates, and final sizes of cotton leaves. Cotton plants (*Gossypium hirsutum* L., cv. DPL-50) were grown in daylit plant growth chambers with temperature and CO_2 as controlled variables. The average air temperatures were 17.8, 18.7, 22.7, 26.6, and 30.6°C with CO_2 treatments of 350 and 700 ìmol mol^{-1} at each temperature. There was no significant effect of CO_2 on leaf initiation rates except at high temperatures during the later part of the season. Temperature affected the final leaf sizes, duration of expansion, and rate of expansion. High CO_2 increased final leaf size and rate of leaf expansion, and the effect was more pronounced at higher temperatures. The increase in whole plant leaf area with doubling of CO_2 was due to small increases in individual leaf sizes and a large increase in number of leaves on fruiting and vegetative branches.

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Carbon Dioxide and Temperature Effects on Stem Extension, Node Initiation, and Fruiting in Cotton

Vangimalla R Reddy, K R Reddy & Basil Acock

Submitted to AGRONOMY JOURNAL

Interpretive Summary: Based on our long-term CO_2 and temperature studies with cotton, it is concluded that floral initiation, measured by days from emergence to first square, is temperature dependent and CO_2 enrichment has no effect on this process. Apparently, floral initiation is not limited by carbon supply in our ambient CO_2 environment and increasing carbon supply by doubling CO_2 does not speed this process. The addition of nodes on the main stem is also temperature dependent, and the node addition rate is not constant at any temperature during the entire growing season. Increasing CO_2 from 350 ìmol mol^{-1} to 700 ìmol mol^{-1} has no effect on node addition rate before flowering across a wide range of temperatures. However, two additional nodes are produced early in the reproductive period at the highest temperature tested. On the other hand, doubling CO_2 increases the number of fruiting sites on each fruiting branch, resulting in a greater number per plant. This shows that the addition of nodes or fruiting sites in ambient CO_2 is source limited. The growth and development of vegetative branches seems to be carbon limited, as more vegetative branches are initiated at lower temperatures in both the CO_2 levels. Growth processes like stem elongation on the main stem and branches are also temperature dependent, but are influenced by carbon supply to a limited extent. The response of cotton to temperature in terms of growth and developmental rates varied with cultivars.

Technical Abstract: The projected increase in global atmospheric carbon dioxide (CO_2) concentration and predicted increases in global surface air temperature have indicated the need for a database on the response of agricultural crops to CO_2 and temperature in various combinations. The objective of this study was to evaluate the direct and interactive effects of temperature and CO_2 on main stem and branch expansion rates, node initiation rates, and fruiting in cotton. Cotton plants (*Gossypium hirsutum* L., cv. DPL-50) were grown in plant growth chambers exposed to natural light levels with temperature and CO_2 as treatments. The average temperatures were 17.8, 18.7, 22.7, 26.6, and 30.6°C during a 70-d experimental period with CO_2 treatments of 350 and 700 ìmol mol^{-1} at each temperature. Plant height and rate of stem elongation increased with increase in temperature and CO_2. The number of main stem nodes and fruiting branches increased with increase in temperature. However, no significant differences were observed in fruiting branch number due to doubling of CO_2 except at 30.6°C. The number of days from emergence to first square was strongly influenced by temperature, and CO_2 had no effect on this process. The number of squares and bolls increased with increase in temperature, and the rate of increase was higher at 700 ìmol mol^{-1} CO_2.

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Carbon Dioxide Enrichment and Temperature Effects on Cotton Photosynthesis and Respiration

Vangimalla Reddy, K R Reddy & Basil Acock

Submitted to AGRONOMY ABSTRACTS

Interpretive Summary:

Technical Abstract: Current projections are that an increase in global atmospheric carbon dioxide (CO_2) concentration and other greenhouse gases may raise air temperature anywhere from 3 to 6°C. This potential change in CO_2 and temperature could have a major impact on growth, development and photosynthesis of crop plants. A set of controlled environmental experiments were conducted to determine the effects of CO_2 enrichment and temperature on photosynthesis, respiration, and dry matter partitioning in cotton. Photosynthesis increased with increase in CO_2 from 350 ìmol mol^{-1} to 900 ìmol mol^{-1}, however the rate of increase was highest from 350 - 450 ìmol mol^{-1} CO_2. Photosynthesis also increased with increase in temperature and the effect of increased levels of CO_2 was more pronounced at higher temperatures.

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Carbon Dioxide Enrichment and Temperature Effects on Root Growth in Cotton

Vangimalla R Reddy, K R Reddy, Mary C Acock & A Trent

Submitted to AGRONOMY JOURNAL

Interpretive Summary: CO_2-enrichment can enhance crop growth and yield under ideal conditions, but if CO_2-enrichment is accompanied by global warming, there may be additional evaporative demands made on the crop. The ability of the crop to meet these demands will depend, in part, on how the root system adapts to changes in aerial temperature and CO_2 concentration. This study showed that roots explored more of the soil profile as aerial temperature increased, and that root distribution down the soil profile was more uniform in elevated CO_2.

Technical Abstract: Understanding how crops might respond to climate change requires knowledge of how roots respond to changes in the aerial environment. Root growth and distribution in cotton (*Gossypium hirsutum* L.) were examined at day/night temperatures of 15/7, 20/12, 25/17, 30/22, and 35/27°C and at CO_2 concentrations of 350 and 700 ìmol mol^{-1}. Plants were grown in controlled-environment chambers with a perspex top under nearly natural daylight. Root observations were made on one 2 m^2 glass side of the soil bin. Most of the roots were found in the top 0.2 m of soil. Root weight was significantly greater in the 700 ìmol mol^{-1} CO_2 treatment at all depths and at all temperatures. Root numbers increased with increased temperature up to 25/17°C. The CO_2 treatment did not affect root numbers. Roots in the lower CO_2 treatment were longer (root length per root axis) and penetrated the soil profile faster at the lower temperatures. In the 700 ìmol mol^{-1} CO_2 treatment, roots were more evenly distributed down the soil profile than in the lower CO_2 treatment. The optimum temperature for root growth was also the optimum temperature for shoot growth (30/22°C). The effect of elevated CO_2 was to make roots heavier, but there was no evidence that this translated into a root system with increased length and more absorbing power. Roots were shorter in elevated CO_2, penetrating the soil profile less rapidly, but perhaps more thoroughly.

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Modeling Cotton Growth and Phenology to Temperature

Vangimalla R Reddy & Basil Acock

Submitted to PROCEEDING OF THE CROP SIMULATION WORKSHOP

Interpretive Summary:

Technical Abstract: Cotton is grown in a wide range of temperature regimes throughout the U.S. Cotton Belt. These crops experience temperature fluctuations throughout the season ranging from 5 degrees C to 45 degrees C which differentially influences growth and development. Minimum, maximum, and optimum temperatures also vary with the stage of plant development and the physiological processes involved. However, most cotton simulation models were developed with data collected from a narrow temperature range, and hence have limited predictive capabilities under temperature extremes. Several studies of cotton growth under high CO_2 conditions examined the plants' response to a wide range of temperatures, including both high and low temperature extremes. A data set derived from these studies was used to construct a model of cotton growth and development. Plant height was modeled as a function of temperature, number of growing nodes, and duration of nodal expansion on the main stem. The rates of approach to flower bud and fruit initiation were modeled as a function of temperature. The rates of pre-fruiting, sympodial, and monopodial leaf expansion were modeled as a function of temperature and existing area of the corresponding leaf structures. The daily increment for new node formation was a function of temperature and plant physiological stresses of the plant. The new model has been verified and is being validated over a range of conditions including temperature extremes.

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Temperature Effects on Cotton Fruit Retention

K R Reddy, H F Hodges, Vangimalla R Reddy & James M McKinion

Submitted to 1992 PROCEEDINGS, BELTWIDE COTTON CONFERENCES

Interpretive Summary:

Technical Abstract: Temperature is a major environmental factor that affects cotton (*Gossypium hirstutum* L.) production. Temperatures of 35 to 40 degrees C are frequently observed in cotton-producing areas. High-temperature environments are sometimes associated with cotton sterility and boll retention problems; however, there is little specific information available on cotton sensitivity to temperature. We conducted a series of experiments in naturally lit growth chambers where the temperature was accurately controlled so we could measure its effects on cotton fruiting site production, abscission of flower buds (squares), flowers, and bolls. Cotton plants grown from seedlings at 40 degrees C for 12 h day shed all their squares. Plants grown from seedlings in the natural environment, then exposed to daytime temperatures of 30, 35, or 40 degrees C during the fruiting period accumulated 47, 5.7, and less than 1 percent, respectively, of their mass as bolls. The time of day when plants were exposed to high temperature did not influence percent boll retention. Number of bolls produced, bolls retained, and percent retention were progressively reduced as time per day at 40 degrees C was increased. Three week exposure to 40 degrees C for 2 or 12 h day resulted in 64 or zero percent bolls, respectively, retained on the plants. Cultivars tolerant to short periods of high temperature would probably be more productive in today's environment and increased tolerance to high temperature will be even more essential in a warmer environment.

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Acclimation of Spinach Plant Foliar Photosynthetic Carbon Metabolism and Dark Respiration to Elevated Atmospheric CO_2 Level

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Submitted to PLANT PHYSIOLOGY

Interpretive Summary: As part of a continuing effort to understand the influence of possible climate change on crop productivity, a study was conducted to determine the influence of elevated CO_2 levels on the photosynthetic and respiratory metabolism in spinach leaves leaves. When spinach plants were acclimated to high CO_2 concentrations, and compared with control plants simultaneously grown at normal CO_2 levels, there was as much as a 1.4-fold increase in their rates of photosynthetic CO_2 assimilation in leaves. Higher photosynthesis rates in the leaves of high relative to normal CO_2 plants ultimately resulted in a doubled dry mass per plant. As in the case of high CO_2 acclimated soybean, there was a dramatic increase in the CO_2 concentration point (where leaf CO_2 assimilation and respiration rates are just balanced) and this was a reflection of elevated foliar mitochondrial respiration in the light. The higher foliar respiration rate apparently was brought on by increased levels and availability of respiratory substrates, e.g. sucrose and starch. Activities of leaf photosynthetic enzymes, e.g ribulose-1,5-bisP carboxylase (Rubisco), were 1.2-1.5 times higher in chloroplasts prepared from high compared with normal CO_2 plant leaves. Thus, in high CO_2 adapted plants, increased CO_2 fixation was due mainly to the higher CO_2 level available to Rubisco, but increased activities of plastid enzymes may have been a contributing factor. This research provides information to plant ecologists and crop modelers to enable them to predict plant behavior at elevated CO_2 levels.

Technical Abstract: Foliar photosynthetic metabolism and respiration rates were examined in *Spinacia oleracea* cv Wisconsin Dark Green plants exposed to high CO_2 levels for 15 days beginning at 21 days after emergence. At 21 days post-emergence, plants were acclimated for 15 additional days in high CO_2 with control plants at normal CO_2. Typical source leaf net photosynthesis rates in high and normal CO_2 plants were, respectively, 1034 ± 40 (measured in 1000 ìmol CO_2 mol^{-1} air) and 751 ± 54 (in 350 ìmol CO_2 mol^{-1} air). In high relative to normal CO_2 plants, growth rate was doubled, and leaf photosynthate levels, were 1/3 higher. High carbohydrate status caused mitochondrial (dark) respiration rates, apparently ongoing in light, to double in magnitude. Activities of ribulose-1,5-bisP carboxylase (Rubisco), fructose-1,6-bisphosphate (C-1) phosphatase, and glyceraldehyde-3-phosphate dehydrogenase were 1.2-1.5 times higher in chloroplasts prepared from high compared with normal CO_2 plant leaves. There was no additional activity of Rubisco conferred by suppling excess units of carbonic anhydrase. Thus, in high CO_2 adapted plants, increased CO_2 fixation was due mainly to the higher CO_2 level available to Rubisco, but increased activities of plastid enzymes may have been a contributing factor. Higher "dark", or mitochondrial respiration rate, ongoing in the light, suggested an increased photosynthate flow into the tricarboxylic acid cycle.

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Acclimation of Young Soybean Plants to High CO_2 Level Increases the Foliar CO_2 Compensation Point and Dark Respiration Rate

J Michael Robinson

Submitted to PLANT PHYSIOLOGY

Interpretive Summary: The influence of elevated CO_2 on the photosynthetic and respiratory metabolism of soybean leaves was investigated to determine the possible impact of climate change on plant productivity. When soybean plants were acclimated to 1000 ìmol mol^{-1} CO_2, there was up to a 1.5 fold increase in their CO_2 assimilation rate, which ultimately resulted in a doubled biomass accumulation. In high CO_2 plants, there was a dramatic increase in CO_2 compensation point, that reflected elevated foliar mitochondrial respiration in the light. In high CO_2 exposed plants, the higher foliar respiration rate apparently was brought on by increased levels and availability of respiratory substrates, e.g. sucrose and starch. Increased plant growth was positively correlated with increased foliar respiration rate. There was no inhibition of CO_2 assimilation in leaves of high CO_2 treated plants. Comparative measurements of net CO_2 assimilation rate revealed that there was a repression of the ability of the source leaves of high CO_2 plants to absorb, transport and/or concentrate CO_2 when CO_2 was present at levels below 600 ìmol m^2 s^{-1}. However, this did not inhibit growth at high CO_2, suggesting adaptation of foliar CO_2 absorption mechanism(s) to high CO_2. These data should enable plant ecologists and crop modelers to predict plant behavior at elevated CO_2 levels.

Technical Abstract: A study to further examine the influence that high CO_2 acclimation exerts on soybean foliar photosynthetic carboxylation capacity, CO_2 compensation concentration (in the light), and dark respiration. *Glycine max* (L.) Merr. cv Amsoy plants were propagated in growth chambers maintained with 650 ìmol m^2 s^{-1} white light, 14 h light-10 h dark cycle, 27°C continuous, and 65% RH, for 10 days post-emergence (PE) in an ambient atmosphere containing 350 ìmol mol^{-1} CO_2 (normal CO_2 plants). At 10 days PE one-half of the plants were transferred to a growth chamber with identical conditions except that the atmosphere in the chamber contained CO_2 at 1000 ìmol mol^{-1}; these plants were acclimated for 12 additional days (high CO_2 plants). CO_2 enrichment of soybean plants increased CO_2 assimilation rate and doubled biomass accumulation. There was a dramatic increase in the foliar CO_2 compensation (measured in the light), and this was a reflection of elevated foliar mitochondrial respiration in the light. In high CO_2 exposed plants, the higher foliar respiration rate apparently was brought on by increased levels and availability of respiratory substrates. Comparative measurements of foliar net CO_2 photoassimilation rate as a function of CO_2 concentration revealed a repression in the ability of source leaves of high CO_2 soybean plants to absorb, transport and/or concentrate CO_2 when CO_2 was present at levels below 600 ìmol mol^{-1}. However, this did not inhibit plant growth in high CO_2 plants, since their foliar CO_2 absorption mechanism(s) had adapted to the presence of 1000 ìmol mol^{-1} CO_2.

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Response of Growth and Photosynthetic Carbon Assimilation in Spinach Plants to Prolonged Exposure to Elevated CO_2 Level

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Submitted to PROCEEDING OF 1992 ANNUAL MEETING OF AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS, PITTSBURGH, PA

Interpretive Summary:

Technical Abstract: Foliar photosynthetic metabolism and respiration rates were examined in young, growing spinach plants exposed to high CO_2 level for 12-25 days. *Spinacia oleracea* cv Wisconsin Dark Green plants were propagated from emergence in growth chambers maintained with a 12h light-12h dark cycle, 650 ìmol m^2 s^{-1} white light, 25°C continuous, and 65% RH for 10-12 days post-emergence (PE) in an atmosphere containing 350 ìmol CO_2 mol^{-1} air (normal CO_2 plants). At 10-12 days PE, 1/2 of the set was transferred to a growth chamber with identical conditions except that the CO_2 level was 1000 ìmol CO_2 mol^{-1} air (high CO_2 plants). Plants were acclimated for 12-25 additional days in high or normal CO_2. Typical source leaf net photosynthesis rates (expressed as ìmol CO_2 fixed per dm^2 h^{-1}) in high and normal CO_2 plants were, respectively, 1034 ± 40 (measured in 1000 ìmol CO_2 mol^{-1} air) and 751 ± 54 (in 350 ìmol CO_2 mol^{-1} air). In high relative to normal CO_2 plants, growth rate was doubled, and leaf photosynthate levels, e.g. sucrose, were 1/3 higher. Mitochondrial (dark) respiration rates in high compared with normal CO_2 plant leaves, were, respectively, 185 ± 31 and 97 ± 13 ìmol mol^{-1} CO_2 evolved per dm^2 h^{-1}. Ribulose-1,5-bisP carboxylase (RuBPcase), fructose-1,6-bisphosphatase, and triose phosphate dehydrogenase activities were 1.2-1.5 times higher in chloroplasts prepared from high compared with normal CO_2 plant leaves. In high CO_2 adapted plants, increased CO_2 fixation was due mainly to the higher CO_2 level available to RuBPcase, but increased activities of plastid enzymes may have been a contributing factor. Higher dark respiration rate suggested an increased photosynthate (anaplerotic) flow into the TCA acid cycle potentially providing an increase in carbon skeletons for more amino acid syntheses.

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The Role of Metabolite Regulation in Starch Synthesis in the Leaves of CO_2 Enriched Soybean Plants

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Submitted to PLANT PHYSIOLOGY, PROCEEDINGS OF 1992 AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS MEETING, PITTSBURGH, PA and to PROCEEDINGS INTERNATIONAL SYMPOSIUM ON GASEOUS AIR POLLUTANTS & PLANT METABOLISM, BLACKSBURG, VA

Interpretive Summary: In order to understand the influence of elevated CO_2 levels on crop productivity, a study was conducted to determine how increased CO_2 affects carbon metabolism. When soybean plants are acclimated to high concentrations of CO_2, there is a 1.5 fold increase in their foliar photosynthetic CO_2 assimilation rate. This increase in photosynthesis not only results in a 2-fold increase in biomass, but also an increase in synthesis and accumulation of carbohydrates such as starch and sucrose. Metabolic conditions in the leaves of high CO_2 acclimated soybean plants favor an increase in activity of enzymes in the starch synthesis pathway. This occurs in part, because hexose phosphate metabolites involved in the starch synthesis processes increase in concentration during the higher rates of photosynthesis. Additionally, 3 carbon photosynthetic metabolites, such as 3-phosphoglyceric acid, are increased in levels in the chloroplasts of high CO_2 acclimated plants. This serves to greatly increase the activity of a major rate determining enzyme involved in the starch synthesis pathway through activation of this enzyme. The result of this "upregulation" is an increase in foliar starch synthesis. This research provides information to plant ecologists and crop modelers to enable them to predict plant behavior at elevated CO_2 levels.

Technical Abstract: *Glycine max* (L.) Merr. cv Amsoy plants were propagated in growth chambers maintained with 650 ìmol m^2 s^{-1} white light, 14 h light-10 h dark cycle, 27° C continuous, and 65% RH, for 20 days post-emergence (PE) in an ambient atmosphere containing 330 ìmol CO_2 mol^{-1} air (normal CO_2 plants). At 20 days PE, one-half of the plants were transferred to a growth chamber with identical conditions except that the atmosphere in the chamber contained CO_2 at 1000 ìmol mol^{-1} air for 7 additional days (high CO_2 plants). After 7 days of high or normal CO_2 exposure, rates of foliar net photosynthesis (APS) were measured. Plant organs were sampled into liquid N_2, lyophyllized, extracted, and quantitated for starch, sucrose, and phosphorylated metabolites. APS rates for source leaves of high CO_2 plants (measured in 1000 ìmol CO_2 mol^{-1} air) compared with those of normal CO_2 plants (in 330 ìmol CO_2 mol^{-1} air) were respectively, 1136 and 683 ìmol CO_2 fixed dm^2 h^{-1}. During illumination, high compared with normal CO_2 plants exhibited 2-7 times higher starch levels in all organs including leaves, stems, and roots. Leaves from high compared with normal CO_2 plants possessed, respectively, 50% and 7% of their dry weight as starch. The foliar concentrations of glycerate-3-P (PGA); fructose-6-P (F6P) glucose-6-P (G6P) and G1P in the high CO_2 plants suggested that a causal factor of elevated starch accumulation was higher activity of one or more rate limiting enzymes in the starch synthesis pathway; e.g. PGA is a positive effector and G1P is a substrate for ADPGlucose pyrophophorylase, a very rate limiting enzyme in the starch synthesis pathway.

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Photosynthetic Acclimation to Elevated CO_2 Occurs in Transformed Tobacco with Decreased Ribulose 1,5-Bisphosphate Caraboxylase/ Oxygenase Content

Richard C Sicher, Diane F Kremer & Steven R Rodermel

Submitted to PHYSIOLOGIA PLANTARUM

Interpretive Summary: Photosynthetic rates of terrestrial plants increase about 50% in atmospheres containing twice ambient atmospheric carbon dioxide levels. However, an adaptation to enriched CO_2 typically occurs during long term growth studies. One of the physiological mechanisms responsible for photosynthetic acclimation to elevated CO_2 has been investigated. An inhibition of photosynthesis was observed in tobacco plants after approximately one week of growth in enriched CO_2, but only in high rather than low light experiments. An inhibition of photosynthesis in CO_2 adapted plants occurred when there was an imbalance between leaf carbohydrates and their utilization in roots and other organs. Photosynthetic acclimation to elevated CO_2 was also studied using genetically modified plants with decreased photosynthetic capacity. Total leaf protein levels of both the normal and genetically modified plants decreased during growth in elevated CO_2. These findings indicate that an inhibition of protein synthesis occurs during photosynthetic acclimation to elevated CO_2. These results are important in evaluating possible plant and crop responses to increased atmospheric CO_2 and global climate change.

Technical Abstract: Inhibition of net carbon assimilation rates during growth at elevated CO_2 was studied in transgenic tobacco plants (*Nicotiana sylvestris* L.) containing antisense DNA sequences to the rbcS gene of Rubisco. Large and medium phenotype tobacco plants, containing 0 or 1 copy of antisense rbcS DNA, respectively, were obtained from selfed progeny of the original Line 3 transformant (Rodermel et al. 1988 Cell 55: 673-681). Rubisco protein levels were 1.3 and 0.5 g m^2, in large and medium phenotype tobacco plants, respectively. Assimilation rates of large and medium plants increased 22% and 71%, respectively, when transferred from low (35 Pa) to high (70 Pa) CO_2 chamber air at high irradiance (900 ìmol m^2 s^{-1}). However, after 10 d growth, assimilation rates of the large and medium plants in the high and ambient CO_2 chambers were about equal. Rubisco activity, total chlorophyll and soluble leaf protein levels also decreased in large and medium plants after 10 d growth in enriched compared to ambient CO_2 chamber air. A suppression of photosynthesis was not observed in large or medium sized tobacco plants grown in enriched CO_2 at low irradiance (450 ìmol m^2 s^{-1}). These findings suggested that photosynthetic acclimation to enriched CO_2 occurs in tobacco plants with transgenically decreased Rubisco levels and suggested that adaptation to elevated CO_2 was precipitated by an imbalance between sink and source organs on the plant.

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Parameterization of Surface Heat Fluxes Above Forests with Satellite Thermal Sensing and Boundary Layer Soundings

Wilfried Brutsaert, Ann Hsu & Thomas J Schmugge

Submitted to JOURNAL OF APPLIED METEOROLOGY

Interpretive Summary: Forests are known to exert a strong control on the climate and the hydrology of major portions of the Earth. Key factors in this respect are the turbulent fluxes of sensible heat and latent heat at the surface. Because forested regions tend to be sparsely populated, many of them have not been monitored very well and much remains to be learned about the physical and biological mechanisms governing their interaction with the turbulent atmosphere. In sparsely populated regions, remote sensing from satellites should be able to furnish much needed information. However, progress has been slow in this area. In fact, there is a common belief that some of the more obvious procedures, making use of remotely sensed surface temperatures, together with air temperatures, may not be appropriate to estimate surface heat fluxes from forest. The primary reason for this is that the surface temperature of a forest canopy is usually close to that of the ambient air, so that their difference tends to become lost in the noise; this has hampered the practical application of standard heat transfer formulations. As will be shown herein, this difficulty can be resolved by using satellite surface temperatures, not in conjunction with standard air temperature measurements near the canopy, but instead with measurements higher up in the atmospheric boundary layer (ABL). Thus, it is the purpose of this paper to illustrate the feasibility of determining the surface flux of sensible heat from forests with surface temperatures measured by satellite together with soundings of temperature aloft in the unstable ABL.

Technical Abstract: Thermal remote sensing from a satellite platform can be used in conjunction with temperature and wind soundings in the boundary layer to determine the surface sensible heat flux from forests at the regional scale. The underlying formulation is derived on the basis of similarity principles applied to the unstable turbulent boundary layer. This is illustrated by data acquired during the HAPEX-MOBILHY (Hydrologic Atmospheric Pilot Experiment-Modelisation du Bilan Hydrique) conducted in spring and summer, 1986 over a 100 X 100 km square in southwest France. The northwest third of the area is covered by the Landes Forest. The surface temperatures for a 25 x 25 km square area in this region were determined from the NOAA-9 AVHRR channels 4 and 5. Atmospheric corrections were applied with Lowtran-7 and the measured atmospheric profiles. The atmospheric profiles were obtained by interpolation of data from radiosondes launched from a clearing in the forest. Calculated fluxes were compared with those measured above the forest at the Institute of Hydrology tower, some 4.5 km from the radiosonde launch site. The comparisons were favorable for 6 clear days but not for a day with partial cloud cover. Results show that the accuracy of the surface temperature measurements should be better than 0.5 K.

TEXTRAN

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Effect of Metabolic Intermediates on the Accumulation of Polyamines in Detached Soybean Leaves. I: Factors Involved in the Control of Arginine Decarboxylase

Frank J Turano & George F Kramer

Submitted to PHYTOCHEMISTRY

Interpretive Summary: Elevated polyamine levels have been observed in plants after exposure to different types of environmental stress, such as mineral deficiency, low pH, osmotic shock, SO_2, O_3, and UV-B radiation. Exogenously added polyamines may play a key role in the plant defense mechanism against stress. Polyamines act as free radical scavengers, cations that balance pH, and/or bind to membranes via ionic interactions in order to provide protection against environmental stress. Recently, however, several laboratories have proposed that polyamines are a means of detoxification of ammonia which is released in plants cells after exposure to stress. It has been suggested that upon stress there are a series of events: 1) release of ammonia, 2) an increase in arginine biosynthesis and 3) an increase in polyamine titers. Thus, there may be a strong correlation between conversion of ammonia into arginine and/or polyamines and tolerance to certain types of environmental stress. We utilize a detached soybean leaf system to gain a greater understanding of the factors that control the regulation of polyamine accumulation. In this study, we determined how various carbon and nitrogen compounds interact to effect polyamine accumulation. Using inhibitors we were able to determine that one enzyme, arginine decarboxylase (ADC), controls polyamine accumulation in this system. These findings will assist plant physiologists, molecular biologists and geneticists in their efforts to increase the tolerance of crop plants to environmental stresses.

Technical Abstract: We have developed a detached leaf system in soybean to test the effects of various nitrogen and carbon compounds on polyamine accumulation. This system was utilized to determine the regulatory role of arginine decarboxylase (ADC) or ornithine decarboxylase (ODC) 2 enzymes involved in the biosynthesis of polyamines in plants. Leaves from 21-day-old soybeans were incubated in buffered solutions containing various nitrogen and carbon compounds separately or in combination. After a 6-hour incubation, polyamine titers were determined and compared against buffered controls. Leaves incubated in solutions containing 20 mM ammonia, glutamine, arginine or citrulline had increased putrescine and spermidine titers. The largest increase (16-fold) in putrescine was observed in leaves incubated in citrulline. Polyamine titer in leaves incubated in tricarboxylic acid (TCA) intermediates were lower than in buffered controls. Leaves that were incubated in solutions containing both ammonia and a TCA cycle intermediate had polyamine titers similar to controls. A similar reduction (79%) in polyamine titers was observed in leaves incubated in both citrulline and a-ketoglutarate suggesting a strong interaction between carbon and nitrogen availability on polyamine accumulation. Experiments involving specific inhibitors of ADC and ODC revealed that the accumulation of polyamines was predominantly due to ADC and not ODC activity. Polyamine accumulation also appears to be dependent on light and protein synthesis.

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Impact of Drought Stress on Protein Synthesis in Developing Cotton Seeds

Eugene L Vigil & Tung K Fang

Submitted to PROCEEDING OF 1991 BELTWIDE COTTON CONFERENCE, JAN. 6-10, 1991, NASHVILLE, TN

Interpretive Summary:

Technical Abstract: The impact of severe drought (water withholding) on protein synthesis during cotton (Gossypium hirsutum L var. DPL 551) seed development was examined using potted plants of identical age grown under glass. Flowers at anthesis were tagged and labeled as to branch and boll position. Embryos used for radiolabeling were excised from ovules in the maturation period of seed development, i.e. 20 to 45 days post anthesis (DPA). Storage of protein during the maturation stage involves gene activation and translation of a number of stage-specific, messenger RNA transcripts. In this study we tested the hypothesis that severe drought directly affects the developmental program for seed ripening. Our experiment was designed to determine at what age during the maturation period developing embryos are most sensitive to severe drought stress. Tagged bolls from the same branch and boll position and equivalent chronological age were used for radiolabeling. The impact of 10 days of severe drought on the pattern of incorporation of 35S methionine into protein of cotyledons and axes was compared to controls with samples differing by 5-day intervals, i.e. 20, 25...45 DPA for controls and 20-30, 25-35...40-50 DPA for drought-stressed plants. Labeled proteins in tissue-free homogenates were separated on 10% SDS gels and autoradiographs from these gels scanned for differences in silver density. A significant result was the absence of distinct radiolabeled bands for high molecular weight (72 and 68 kD) storage protein precursors in embryos (cotyledons and axes) from bolls being 35 DPA or older at the beginning of drought treatment. These results suggest that severe drought affects a major transition in the development program from maturation to post abscission and desiccation programs.

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Progress Report on the Relationship Between Fiber and Seed Quality as Affected by Drought Stress

Eugene L Vigil & Devron P Thibodeaux

Submitted to PROCEEDING OF 1991 BELTWIDE COTTON CONFERENCE, JAN. 6-10, 1991, NASHVILLE, TN

Interpretive Summary:

Technical Abstract: Our collaborative research program is aimed at assessing the potential impact of drought stress on fiber development and seed maturity in cotton. Since immature fibers have been identified as a cause for white specks in dyed yarn and cloth, we are interested in determining whether specific stages of fiber maturation are more sensitive to drought stress, resulting in higher percentages of immature fiber and seeds. Analysis of data for lint fiber from cotton (*Gossypium hirsutum*, var. M-8) seed in open bolls after exposure to 25 days of severe drought (water withholding) revealed uniform immaturity of fiber based on measurements of circularity, cell wall area, and fiber mass. The lint fiber were at the early stage of secondary wall deposition at the time of exposure to severe drought. Data obtained with the Advanced Fiber Information System (AFIS) are reported on distributions of single fiber area and circularity for seeds taken from different positions in the locule and fibers taken from different parts of the seed. These data, when combined with seed weight measurements, provide evidence that severe drought stress applied to plants with bolls at the beginning of fiber and seed maturation phase, significantly and uniformly impacts fiber maturation and seed mass. This response was observed for drought-stressed seeds from bolls in the first position of upper and lower branches. This is the first time that accurate measurement on fiber quality have been presented for individual fibers from single seeds. Our findings may be of assistance to cotton producers faced with obtaining uniform fiber and help answer how adjustments to changes in environmental conditions can narrow differences in fiber quality and yield.

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Inhibition of Whole Plant Respiration by Elevated CO_2 as Modified by Growth Temperature

Lewis H Ziska & James A Bunce

Submitted to PHYSIOLOGICA PLANTARUM

Interpretive Summary: Elevated atmospheric carbon dioxide (CO_2) and other greenhouse gases may result in global change including an increase in average temperature. High CO_2 has already been shown to stimulate photosynthesis and growth in a number of plants. Crop growth depends on both photosynthetic carbon gain and respiratory carbon loss. Respiration rates, in particular, will be affected by temperature. However, little work has examined the interaction between CO_2 and temperature on respiration in plants. We therefore studied the impact of current and double current levels of CO_2 on respiration and growth in two perennial crops, alfalfa and orchard grass, grown at 15, 20, 25 or 30C. Elevated CO_2 inhibited total respiratory carbon loss for both species at low temperature (15 or 20 C). Respiration was separated into two components: (1) that utilized to support new growth; and (2) that required to maintain existing structure. Inhibition of respiratory carbon loss at high CO_2 was primarily the result of diminished maintenance respiration. This study suggests that perennial plants may serve as stronger sinks for increases in atmospheric carbon than initially anticipated, but that this effect will depend on temperature.

Technical Abstract: Two herbaceous perennials, alfalfa (Medicago sativa) and orchard grass (Dactylus glomerata) were grown from seed in controlled environmental chambers at two CO_2 concentrations (350 and 700 ìmol mol^{-1}) and four constant day/night temperatures of 15, 20, 25 and 30 C to determine changes in growth and whole plant CO_2 efflux. Growth at elevated CO_2 significantly enhanced total plant biomass at all temperatures relative to ambient CO_2, but the enhancement effect declined significantly as temperature increased. Whole plant respiration significantly declined at 15 and 20 C in D. glomerata on an area, weight or protein basis, and at 15 C in M. sativa on a weight basis. Separation of total plant respiration into that required for growth (Rg) and maintenance (Rm) showed no effect of elevated CO_2 on inhibition of Rg for either species. However, the ratio of Rm at ambient compared to elevated CO_2 significantly increased at all temperatures in M. sativa and in 3 out of 4 temperatures in D. glomerata. Data from the current study indicate that inhibition of total plant respiration at elevated CO_2 is primarily a result of reduced Rm, especially at lower temperatures. Results from this study suggest that potential increases in global temperature could limit the effect of elevated CO_2 on respiration in two perennial species.

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The Influence of Elevated CO_2 and Temperature on Seed Germination and Soil Emergence

Lewis H Ziska & James A Bunce

Submitted to FIELD CROPS RESEARCH

Interpretive Summary: The global concentration of carbon dioxide has increased 32% since the start of the industrial revolution. Unless checked, current increases in population and energy demand could potentially result in a doubling of current levels of atmospheric CO_2. Potential increases in CO_2 can impact the physiology of crop plants because plants use CO_2 as their sole carbon source. To date, little research has examined the role of increased CO_2 on seed germination. In our studies we examined the impact of current CO_2 and (2x) current CO_2 on the differential sensitivy of seeds to germination and emergence. Our data obtained from a comparison of 6 crop and 4 weedy species, indicate that a doubling of CO_2 would result in a greater increase in germination and emergence for weedy species under controlled conditions, and a significant increase in weed seed emergence in the field. Data from this experiment suggest that future increases in global CO_2 may alter the balance betweeen crop and weed species with potential consequences for crop production.

Technical Abstract: Seeds of six crop species, alfalfa, *Medicago sativa* L. cv. "Arc", soybean, *Glycine max,* L. (Merrill) cv. "Williams", maize, *Zea mays* L. cv. # 885, pea, *Pisum sativum* L. cv. "Maestro", sunflower, *Helianthus annuus* L. cv. "Mammoth", and pumpkin, *Cucurbita pepo* L., cv. "Big Max" and four weedy species, *Amaranthus hypochondriacus* L., *Amaranthus hybridus* L., *Chenopodium album* L. and *Abutilon theophrasti* Medic., were grown at two CO_2 concentrations (350 ìmol mol^{-1}, (ambient) and 700 ìmol mol^{-1}, elevated) in growth chambers to determine possible effects on germination and emergence. Elevated CO_2 resulted in a significant increase in the rate and final percentage of germination, especially among the weedy species. In field experiments, elevated CO_2 resulted in a significant increase in the total number of weed seedlings present after 3 weeks. In a second set of experiments using growth chambers, no interaction between increased temperature (20°C and 30°C) and elevated CO_2 was observed. Overall, this investigation suggests that as CO_2 increases, differential changes in germination and/or emergence between crops and weeds could occur.

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